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OUTLOOK ON AGRICULTURE

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The design in linocut on the cover is a composite of drawings from two medieval manuscripts. In the centre is a figure from the works of Matthew Paris, who entered St. Alban's as a monk in 1217. Surrounding this, depicting farming activities throughout the year, are drawings based on MS. from the Benedictine Abbey of Sweifalten, circa 1162.

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FERTILIZERS AND FOOD PRODUCTION

In the thought-provoking article published in the Winter number of this journal, Mr. H. J. Page showed that it would be entirely practicable to double world food production by the end of this century through the use of fertilizers and other methods of agricultural improvement. The contribution that fertilizers could make was derived from the calculation, based on field experiment results, that on the average one ton of nitrogen used as fertilizer can produce enough extra food to nourish some 40 persons for a year.

Another approach to the question of what fertilizers can do to increase food production is to examine the percentage increases in crop yields that have been recorded in fertilizer field trials. Thus the F.A.O. publication *Man and Hunger* (1957) stated that, except in a very few countries, crop production could probably be increased by at least 50%, and in many countries by 100%, through soil fertility practices alone, including crop rotation and the use of fertilizers. These are modest estimates, deduced from the results of trials carried out—as is proper—with prevailing methods of farming, which are primitive in most of the underdeveloped countries; but they do not end the story.

The extent to which fertilizers can increase yields depends very greatly on the standard of farming. Primitive cultivators, using unimproved crop varieties and having little knowledge or control of the many factors that are important for good crops, are likely to get poor returns from the small dressings of fertilizers they apply; but, as the standard of farming improves and high-yielding crop varieties and other new techniques are introduced, larger responses will be secured even from the low rates now used, and much heavier rates, giving still greater returns, will become practicable. Fertilizers are not introduced in isolation in an agricultural development programme but as part of the whole procedure of improving crops and farming practices. The other measures, however, are less effective without fertilizers, and fertilizers give their best responses only when used along with them: there is a positive interaction. Further, the residues of fertilizers accumulating in the soil and the extra supplies of organic matter they produce help to build up soil fertility. It is evident, therefore, that the potentialities of fertilizers in the more backward countries are far from being realized.

These reflections are pertinent when we consider a country like India, where comprehensive and widespread field trials have shown average fertilizer responses of the order of 50% of current yields with wheat and rice. In terms of quantity, however, the increases are small compared with those obtained in more advanced lands, for yields per acre in India average only 660 lb. for wheat and 1140 lb. for paddy rice, which correspond to medieval yields in England or Japan. Today, production per acre of wheat is over 3000 lb. in England while that of paddy rice is around 4000 lb. in Japan, and the upper limits have not yet been reached. This multiplication of yields once obtained by primitive methods can also be achieved in India. Climatic factors may prevent attainment of the very high averages of more favoured lands, yet prizewinning yields of 5000 lb. of wheat and 10,000 lb. of paddy rice per acre have been officially recorded in India, indicating that the normal yields could be increased several-fold by the application of methods already known. Similar considerations apply to the effects of fertilizers in many other underdeveloped countries in Asia, Africa, and Latin America.

We may fairly conclude, therefore, that the direct results of current trials in regions where farming standards are low are likely to underestimate what may be achieved with the help of fertilizers in the future, and although it may be safer to underestimate than to overestimate in such matters the possibilities should be borne in mind. Certainly when better methods of farming become widely adopted, as they surely will, fertilizers will do much more to increase food production than is now commonly believed.

To reach these higher levels of crop production will not be easy, for the practical problems to be solved are many and complex. This aspect is well covered in another F.A.O. publication, *Efficient Use of Fertilizers*, which is reviewed in the present number. This book shows how important fertilizers are for increasing crop production when they are properly used, but it also shows how much skill is needed to use them effectively under the widely ranging conditions of world agriculture. In the underdeveloped countries the greatest problem will be to teach the peasant to apply the new methods, not only of fertilizer use but of farming generally. This will require a far greater increase in farm advisory and extension services than most countries have yet envisaged, and the development of these services is a matter of high urgency in the task of stepping up production in the lands that need food most.

SOIL ANALYSIS IN FARMING

N. H. Pizer

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One of the features of modern agriculture is the rapid development of a closer relationship between its science and its practice, as is instanced here by the use of soil analysis in advisory work. What is done in the laboratory is of direct benefit to the farmer, for the whole object is to find what goes wrong when crops suffer from adverse soil conditions, to devise remedial measures, and to ensure that these are correctly applied in the field.

In many countries soil analysis is in common use as a means of examination of soils to assess conditions that may affect the growth of crops, and to indicate some of the steps that may be taken to improve soil conditions and crop yield. Its practical value depends on the manner in which it is used, on knowledge of soils, crops and farming, on good field work and on experience. Its chief feature is that it provides information on soils which cannot be obtained as rapidly by other means, and this largely accounts for the considerable use that is made of it in all branches of agriculture, horticulture and forestry. It also accounts for the continuous efforts that are being made to extend the use of soil analysis and to speed up existing procedures in the laboratory and the introduction of instruments that replace analytical skill and free the analyst from purely routine work; and it partly accounts for differences between laboratories in the kind of work that is done and in the methods that are used.

In Britain and elsewhere, agricultural advisory services established by the State or industry make considerable efforts to use soil analysis in advisory work as efficiently and effectively as possible. Apart from laboratories with modern equipment and trained staff to carry out analytical work, these services require a number of chemists having a specialized knowledge of the growth and nutrition of crops in relation to the properties, conditions and behaviour of soils in the field. The soil chemist not only studies the soils and crops of a region by methods of investigation and experimentation, but gives advice and guidance to agricultural and horticultural advisers, who are in daily contact with farming, on the soil and crop problems they may encounter. To do this effectively, the soil chemist must train advisers in the techniques of soil and crop examination and study unusual conditions with them. Much of his time must be spent in the field so that he can influence and guide advisers in the field and analysts in the laboratory, and so try to ensure that the efforts of both are not misdirected and that the best advice is given.

The need for organization of this work into its analytical and advisory aspects arises from variability—in soils, growth and requirements of crops, climatic conditions and farming practices—which must be studied separately and in relation to each other when soil problems are being considered.

Variability in soils may influence the root range and growth of crops, the method of sampling of soils for analysis and the treatment that may eventually be recommended. It is present in all soils to some degree and is often made apparent by extreme seasonal conditions of wetness or dryness which cause growth patterns to appear in crops. Where experiments are being put down to provide basic information on the effects of cultural or manurial treatments, or liming, sites are chosen which are not unduly variable and, in the design of the experiment, provision is made for an assessment of the effects of soil variability.

Soils to be sampled for analysis must first be examined for variability, possibly without a crop or the effects of adverse season as a guide, and the method of sampling is determined from the nature of the soil pattern found. Soils that appear to be different should be sampled separately, not mixed together, otherwise considerable errors may be made in the interpretation of soil analysis. The more experienced an adviser is in the field, the more careful does he become in looking for variability and, like the field experimenter, he keeps it as much as possible out of his sample. Where soil conditions are very variable, he may not succeed, and soil analysis then has limited value which is taken into account when advice is given.

Soil acidity commonly shows a distribution pattern of considerable variability which can be followed in the field with a soil indicator. The chief factors responsible are depth and nature of the soil and the uneven application of lime. The pattern may change abruptly across the surface of a field and extend downwards to a very variable depth. Where crops are to be grown that are sensitive to acidity or depend on deep rooting for growth and survival in times of drought (e.g. barley, sugar beet and lucerne), it is essential to know how acidity varies in the ploughed layer and how deeply it extends into the soil, so that steps may be taken that are adequate for treating the worst areas.

Variability in other soil properties that influence crop growth may explain crop failures or poor areas in fields, apart from the findings of soil analysis. Since the mineral nutrients and the moisture that crops require are obtained from the soil, the soil must be accessible to the roots or partial starvation in moisture or nutrients may result. If crop roots are healthy their manner of spread is determined by habit of growth, the distribution of soil pores large enough for them to enter, the distribution of moisture, oxygen, carbon dioxide and nutrients, and the absence of unfavourable acidity or alkalinity. The soil properties involved are physical, chemical and biological.

The physical properties of texture and structure largely determine root range, moisture distribution, drainage and air supply to the roots. Texture, structure, acidity and organic matter influence biological activity and the distribution and retention of mineral nutrients; but in most cultivated soils the supply of nutrients is modified or dominated by previous cropping and applications of fertilizers and farmyard manure. Texture and drainage influence the development of acidity but, as previously stated, the distribution of acidity largely depends on other factors.

PHYSICAL PROPERTIES OF SOILS

Texture was one of the first physical properties of soils to be used in a practical way to assess the tilling properties of soils, moisture retention, drainage, earliness of crop growth, lateness of removal of crops, and whether stock may go on to pastures soon after rain without causing physical damage to the soil. Texture was given quantitative measure by the mechanical analysis of soils into fractions of graded particle size—coarse sand, sand, fine sand, very fine sand, silt and clay—which were examined and studied separately. A textural scale was then introduced, based on the feel and cohesion of the individual soil fractions and of the combinations of them that occur in the field. This scale largely superseded the more lengthy and elaborate mechanical analysis, and it could be used, if need be, to assess roughly the percentages of the fractions in soils. One of the best textural scales in the writer's experience is the U.S. official textural scale; it has a logical basis and structure and uses the names of the soil fractions, apart from the word loam, to describe each texture. More sub-divided scales for local use have appeared, but it is doubtful if they have any greater practical value.

Soil structure has proved more difficult than soil texture to understand, describe and measure; and only in recent years has much progress been made, although its importance to crops has long been recognized. It concerns the formation of soil particles into primary aggregates and the arrangement of these into larger ones, the nature of the forces of orientation, and the nature and stability of binding agents. The subject is too large to do much more than mention here, but the kinds of soil structures and their stabilities depend to some extent on soil texture, organic matter, ferric hydroxides, rapid wetting, drying, freezing and thawing, effects of roots, the relative proportions of calcium and sodium ions adsorbed by clay and organic matter, position of the part of the soil in the soil profile, and mechanical treatment.

The tendency for aggregation depends on properties of clay and organic matter and dominance of the effects of adsorbed calcium over sodium; it is reduced by the presence of much fine sand, very find sand and silt, which tend to flow when soils are thoroughly wetted. Aggregation may not be very marked in textures lighter than clay loam, either through lack of sufficient clay and organic matter or through the adverse properties of fine sand and silt. Textural assessment is thus of importance when farmers are seeking ways of improving the structure of soils, for it will differentiate the difficult soils. Aggregation of soils of all textures may become difficult or impossible when adsorbed calcium ions fail to counteract adsorbed sodium ions—as may happen after large amounts of salt have been added to soils, either as fertilizer or as a result of salt-water flooding—except when ferric hydroxides are the main binding agents, since they are not loosened by sodium ions.

The main structural defects are cloddiness of the top soil, the presence of layers that are compacted or partly compacted and impede root development, and of layers that are impervious to water or absorb water very slowly. Cloddiness may deny plant roots access to the part of the soil where most of the mineral nutrients are held and may be bad enough to cause nutritional deficiency unless the condition is countered by the application of fertilizers, particularly nitrogen. Cloddiness is of two extreme kinds: that caused by compression of an essentially granular soil when it is on the wet side; and that formed by slaking of an unstable tilth by water, with or without compression. Clods of the first kind are often accessible to roots and break apart as roots enter them and grow in thickness. Clods of the second kind have finely porous structures, so that they attract and hold water excessively in wet times and become hard and rigid when they dry out. Roots have difficulty in entering them because the pores are too fine or aeration is faulty, but if they do gain entry the clods may dry out into a rigid condition against which root expansion is ineffective—in the language of the farmer the roots become "strangled". Compact layers that are infilled with ferric hydroxides are usually impervious to water and are described as "drummy" in eastern England.

Because soil structures affect root development and water movement, it is important to examine them within and below the root range of crops and to visualize how they may change with differing conditions throughout the year. A visual examination and description of soil structures in a soil profile is the first step, and the use of a hand lens will show the nature of the main binding agent—organic matter or ferric hydroxides. Textural assessments will indicate whether a structure is likely to be unstable through containing too little clay or too much fine sand and silt, and simple tests of allowing water to enter dry fragments rapidly and slowly will show whether water will cause slaking, or whether the structure is very stable to water, as ferruginous types usually are.

Measurements of structural stability are designed to determine (1) the effect on granule size of vigorous movement of the soil in water, (2) the shattering effect on soil fragments of the impact of water droplets of known size and kinetic energy, and (3) the effect on the diameters of soil pores of slow and rapid wetting of the dry soil with water. In the third determination, slaking with water has seemed to the writer to come most nearly to conditions in the field, certainly for layers in the subsoil, but also for the surface soil after it has become protected by crop foliage from the impact of rain drops but still remains susceptible to the slaking effects of water. In advisory work, observations of the effects of rapid and slow wetting are usually adequate, but measurements of slaking properties become necessary where slow improvement in soil structure due to soil treatment is being followed.

Where structural stability is exceptionally weak and this is not due to texture or the nature of the binding agents, the presence of exchangeable sodium in the soil may be suspected and the soil should then be examined for sodium and calcium "deficit" by Schofield's method.

Physical examination of soils in the field is now commonly used by advisers to assess rooting conditions, moisture retention by soils, slaking of soil layers by water, and drainage conditions. Some obvious applications are to fields where crops that are particularly sensitive to adverse conditions are being grown, where irrigation is contemplated, where drainage by mole or pipe seems necessary, and where subsoiling may be of benefit. It may also indicate where a change in cultural practice may be desirable or a soil need resting under a long ley.

CHEMICAL PROPERTIES OF SOILS

The chemical properties of soils, unlike the physical properties, can seldom be detected by our senses. Fragments of calcium carbonate can be seen in soils and the presence of organic matter is recognizable, but our senses are unable to detect mineral nutrients or acidity, and soluble salts only when they are excessive and have specific effects on our sense of taste. For all these soil properties chemical methods of measurement are necessary.

Sampling Procedure

The general procedure in all laboratory techniques, once a particular measurement seems likely to have practical value, is to achieve its reproducibility by defining the conditions at each stage, and its speed in use by selecting methods that are suitable for simple routine and final measurement by physical instruments. It is desirable for routine purposes that all soils should be examined by the same methods and differences between soils taken care of when the results of analysis are being interpreted.

The first stage in soil analysis is to define the method of preparation of the sample from its condition as received from the field to a condition of greater uniformity and suitability for laboratory work. This involves air drying at a temperature not exceeding about 80° F. and breaking or grinding the dried soil until it passes through a sieve with holes of 2-mm. diameter or, for some purposes, 1-mm. diameter. The soil is then in a fairly uniform condition from which small samples can be taken for analysis with the probability that, if analytical technique is good, reproducible results will be obtained. All parts of the soil sample are subjected to the same thorough treatment, as they almost certainly would not be in the field when invaded and attacked by crop roots. This is a point to remember when the results of soil analysis are being considered in relation to soil properties that affect moisture retention and root development of crops, and is one reason for careful soil examination and sampling in the field.

There is no alternative in the laboratory to standardized procedures and the selection of appropriate standard conditions. For the results, however, to have practical value they must be calibrated against crop behaviour in the field. This is a long and tedious business. It may begin with existing long-term experiments on field stations and husbandry farms to obtain basic working data; these are then tested by observation of crops on farm fields and analysis of the soils on which they are growing, the particular purpose being to establish critical levels at which crops begin to fail or suffer a reduction in yield, and to obtain some measure of the influence of soil type, soil conditions, climate and season on these levels. With this information it then becomes possible to begin a more critical examination of the responses of the principal crops to fertilizers in relation to levels of nutrients in the soil as shown by soil analysis, soil type, climate and type of farming. The variables are many and must be dealt with, in the first instance, by grouping crops and soil types, eliminating such variables as bad tilths and other poor rooting conditions, and averaging seasons.

In view of all these difficulties it may seem surprising that soil analysis has been useful and at times of considerable value to farmers. It is of most value for detecting soil conditions that are critical to crops and deficiency levels of nutrients in soils, for which more than average rates of application of fertilizers are needed; it is less certain, partly through insufficient experimental data, in determining the effects of nutrients on responses of crops to fertilizers. At all times it is most successful when combined with careful examination of soil conditions and crop behaviour, and knowledge of the system of farming and use of fertilizers.

Soil Acidity and Lime-requirement

The determination of soil acidity is typical of the inherent difficulties imposed by field conditions on chemical methods of soil analysis and how they are overcome. With modern equipment and the glass electrode it is easy to determine the acidity of a solution on the *p*H scale with a fair degree of accuracy, but almost impossible to determine the *p*H of the water films in soils with which roots are in contact. Moreover the *p*H of these films changes as water is added or removed from them, partly as a result of changes in salt concentrations, temperature and root activity, and roots must suffer considerable local fluctuations in *p*H of the water films. In the laboratory, the soil sample is dispersed and suspended in a relatively large volume of water (usually 1 volume of soil to 2½ volumes of water), and the *p*H of the suspension is measured at laboratory temperature which in Britain is usually 18–20° C. The *p*H value so obtained may be a whole unit higher than that occurring in water films, but this is immaterial if interpretation of the *p*H value is based on extensive calibration as already described.

There still remains the need to take into consideration other soil factors in assessing the effects on crops in the field, such as the greater severity of acidity to crops on sandy soils of low moisture-holding capacity and low exchangeable calcium, its lower severity where these properties are both high, as on the peats, and the possible adverse effects of soluble aluminium and manganese in medium and heavy soils with *p*H values below 5·5.

The determination of lime-requirement is relatively simple. Two *p*H measurements are made, one in water and the other in a standard solution of lime water; and from the two figures a calculation is made of the amount of lime needed to raise the *p*H to 6·5, assuming a direct relationship between *p*H and lime added to the soil. Results are commonly expressed as cwts per acre of calcium carbonate required to raise a 6 in. depth of soil to *p*H 6·5. The application of this figure to field conditions is less simple. Usually it is multiplied by a factor of 2 to allow for poorer distribution of lime, and by a further factor if a greater depth of soil than 6 inches is to be limed, and possibly by yet another factor if a coarse grade of lime is to be applied. Where acidity extends deeply into the soil some of the lime may be ploughed in and a grade of lime used in which the particles are so fine that they will be carried down mechanically by drainage water.

Potassium

Potassium occurs in soils in a number of forms which vary in their availability to plant roots. In the forms that are most available the potassium is attached to the exposed surfaces and edges of the clay minerals and to organic matter; much less accessible or available is potassium which lies between the lattice layers of the illite group of clay minerals or is combined in stable silicates. In the first of these instances the attached potassium is readily exchanged for other cations, and a common analytical procedure for displacing it is to shake the soil with a solution of a sodium or ammonium salt or a dilute acid, when the sodium, ammonium or hydrogen ions exchange with potassium and bring it into solution; alternatively the soil may be leached with a solution of an ammonium salt, when displacement of potassium is usually more complete. The potassium in the soil extract can be very quickly estimated by using a modern flame photometer and is usually expressed as p.p.m. of soil or of extract. It matters little which method of expression is chosen, for the figures are used to express relative availability on a scale of values from very low to very high, which have been assessed by calibration against crop symptoms and responses to potassium fertilizers in the field.

Interpretation of the levels of availability of potassium as judged by soil analysis depends on a number of factors of which the more important are root range, root activity, rate of growth of the crop, soil texture, soil structure and moisture retention. For most farm crops, a sample of the ploughed or cultivated layer of soil is analysed. It is assumed that this layer, when in good tilth and adequately moist, will supply most of the potassium required during the growing period since rooting is usually most active and extensive in the top soil and levels of available potassium commonly fall off sharply in the soil below. Crops that root deeply, however, such as sugar beet and lucerne and many tree fruits, may obtain a useful proportion of their potassium from the deeper soil if the levels available there are not very low. This may happen on many alluvial soils and clay soils that are well drained and extensively fissured to a considerable depth, such as some of the Boulder Clays, but not on most of the older loamy sands, sandy loams and loams, or on heavier soils of bad structure.

Calcium

Calcium occurs in soils in the form of stable aluminosilicates, the fairly stable calcium phosphate, apatite, calcium carbonate and sulphate, and attached to the exposed surfaces and edges of clay minerals and organic matter from which positions it can be displaced by exchange with other cations. The same solutions are used for displacing exchangeable calcium as for exchangeable potassium. It might be supposed that exchangeable calcium would be a satisfactory measure of available calcium in soils that do not contain calcium carbonate and sulphate; unlike exchangeable potassium, however, exchangeable calcium is abundant in cultivated soils throughout the root range of farm crops, and if it were used as a measure of available calcium it would have to be expressed as a gradient of exchangeable calcium in the soil. Many soils contain calcium carbonate and calcium sulphate in varying amount and, since these are partially or completely soluble in the solutions used for displacing exchangeable calcium it becomes difficult if not impossible to make a true estimation of exchangeable calcium.

Calcium carbonate and calcium sulphate also provide calcium to roots that make contact with them, but there is no means of knowing how far this takes place, so that estimates of available calcium are still less realistic in such soils. In advisory practice it is usual to consider that soils contain adequate calcium for crop growth when the *p*H value is satisfactory. There are occasions when it might be useful to have a measure of "active" calcium—for example where calcium appears to lower the uptake of potassium, magnesium or iron by crops, or the solubility of phosphate—but no satisfactory method has been developed.

Magnesium

Magnesium occurs in soils in stable silicates and aluminosilicates, in fairly stable combination in the lattice sheets of the illite and montmorillonite groups of clay minerals, and as exchangeable magnesium in similar positions to exchangeable potassium and calcium. It may also occur as magnesium carbonate, magnesium carbonate combined with calcium carbonate, and as magnesium sulphate.

Magnesium deficiency has been a serious problem in some fruit growing areas for a long time and also in tomatoes and other glasshouse crops, and in recent years it has appeared more widely in many farm crops growing on the lighter textured soils. Magnesium deficiency may be caused by exhaustion of the soil in available forms of the element or its exclusion from plants owing to preferential uptake of other cations, such as calcium and potassium. The trouble may be accentuated by poor root development due to adverse soil conditions or to lack of nitrogen which restricts growth and vigour generally.

In parts of East Anglia, where the problem is not complicated by the presence of magnesium carbonate or sulphate in the soil, it has been possible to obtain a measure of exchangeable magnesium by leaching the soil with normal ammonium nitrate solution. The amount may increase or decrease with depth in the soil, but these changes have only been correlated with observations of magnesium deficiency when the amounts of exchangeable magnesium were very low. There remained many instances of deficiency when the levels of exchangeable magnesium seemed ample. This might have been caused by excess of calcium or potassium; but, since there is no satisfactory measure of available calcium and no practical way of lowering excess calcium, the relation of K to Mg was examined. This showed that if the ratio of exchangeable K to exchangeable Mg were 2 : 1 or less, deficiency might cease to be a problem. Since levels of exchangeable K or Mg can be readily adjusted by withholding K and adding Mg, the effect of bringing the K : Mg ratio to 2 : 1 or less was tried in glasshouses and apple plantations with apparent success. Whether a similar approach can be used elsewhere may depend on whether a satisfactory estimate of exchangeable or available Mg in the soils can be made. Since this work was done, papers by other workers have shown that a narrow K : Mg ratio is apparently of importance in the control of Mg deficiency. Although considerations of K : Mg ratio in soils and its change in value with depth has been of practical value in dealing with the deficiency problem in East Anglia, there have been many instances where delay in root formation—e.g. of the secondary roots of cereals—or renewal of roots or root injury has seemed to be the main cause of malnutrition, and it is probable that much remains to be learned about the field aspects of magnesium nutrition of crops.

Sodium

Sodium occurs in soils in aluminosilicates and in some of the clay minerals, but the chief interest lies in exchangeable sodium and sodium chloride, sodium sulphate and sodium carbonate. There is sound experimental evidence that sodium is a valuable nutrient for sugar beet, mangolds and possibly carrots and that it will increase the yields of these crops, but too much exchangeable sodium in many soils will weaken aggregates and tend to produce a close type of structure that is sticky when wet, hard when dry, and difficult to manage; even light soils may so change that water will not drain through readily and roots may be killed by poor aeration.

Little use has been made of soil analysis to ascertain whether soils contain sufficient sodium for crops like sugar beet, although experiments show that the response to salt is very variable and the ill effects on the physical properties of soils of too much exchangeable sodium are well known. Exchangeable sodium and sodium salts are readily extracted from soils and the sodium is easily measured with a flame photometer, so that it is possible for work on sodium in soils to develop much more rapidly than work on magnesium. Alluvial soils near the coast often contain enough sodium to satisfy the needs of sugar beet, but it is commonly supposed that the older inland soils contain very little exchangeable sodium apart from any that has been added. This may not be so, and even the low levels which occur to a depth of 3 ft. or more may be adequate for sugar beet.

After the coastal floods of 1953, exchangeable sodium and sodium chloride were present together in soils and not easy to separate by chemical methods. R. K. Schofield devised an indirect method of measuring exchangeable sodium which amounts to measuring the calcium needed to replace it, the calcium being called the calcium "deficit" of the soil. This method was extremely useful for estimating the amount of calcium sulphate or gypsum that should be added to soils to keep them in, or restore them to, good physical condition. It is used today on soils near the coast or on soils that have been irrigated with water containing salt, and on inland soils where the physical condition of soils appears to be deteriorating for no other obvious reason. Sodium chloride is estimated from a measure of the chloride content of soils, but experience has shown some chloride may also be present as calcium or potassium chlorides. Damage to crops, however, results from the effects of soluble salts on root activity and specific injury from chloride, and probably no great error is made in the estimate of salt effects by calculating the chloride as sodium chloride, except when other salts such as sulphates and nitrates are present in high amount.

Soluble salts in general are estimated from the electrical conductivity of a water extract of soils, using 1 volume of soil and $2\frac{1}{2}$ volumes of water as in making *p*H measurements. Results may be expressed as conductivity figures or on a logarithmic scale known as the *p*C scale. Much remains to be learnt about the interpretation of conductivity figures, and the situation is not as simple as was originally supposed. The water-holding capacity of soils is at least one factor that must be taken into consideration. Greatest use is made of conductivity measurements in glasshouse soils where residues of salts from fertilizers may accumulate, but sometimes they are used where fertilizers have been placed at heavy rates, e.g. under potato ridges, and the crop appears to be damaged or checked.

Sodium carbonate is seldom found in British soils. Its presence is to be suspected where adverse physical soil conditions are of the same kind as, but more severe than, those produced by exchangeable sodium alone, and where the soil *p*H is as high as 9–10. Patches in this condition are found in fields where plant residues high in sodium have been burnt, most commonly the old stalks from sugar beet or mangold grown for seed. Such patches may remain sterile or in bad physical condition for years unless treated with gypsum and carefully managed. Land that has been flooded by sea water may show the effects of sodium carbonate for a time.

Phosphate

Much work has been done and continues to be done on the relations of phosphates in soils. Water-soluble phosphate as dihydrogen phosphate is the active form in superphosphates, monammonium phosphate, and compound fertilizers containing these materials; but the level possible in soil moisture is very low, and the effectiveness of these fertilizers depends on their localized distribution or placement in soils and on contact of crop roots with them. As soils are repeatedly cultivated, applied phosphates become more thoroughly distributed but seldom move out of the cultivated layer; they also become less available partly because they form combinations in the soil that are too stable for the roots of many crops to remove phosphates from them at a sufficiently rapid rate.

Most of the available phosphate in soils is believed to be adsorbed on the surfaces of clay minerals and organic matter, either directly or through calcium linkages. There have been two main approaches to the problem of measurement: (1) Estimation of the total amount of adsorbed phosphate by extracting the soil with a large volume of a weak acid, e.g. citric, acetic, or lactic acid or mixtures of these. Such extractions are seldom complete, but the phosphate figures obtained have correlated quite well with responses of crops to phosphate fertilizers, except on soils that are high in calcium carbonate or calcium sulphate, like the fen peats, and on those containing iron phosphates which are not readily available to crops yet are dissolved by the extracting acids. (2) Elimination of the water-soluble phosphate under prescribed conditions which allow expression of the phosphate level as a phosphate potential in soils. A present difficulty with this approach is that of measuring very small amounts of phosphate; one method, introduced by R. K. Schofield, has given promising results when tried on experimental plots at Rothamsted.

Between these two methods, the first of which measures a quantity of available phosphate and the second its intensity or level of availability, are others which compromise and attempt to provide both measures by having a narrow ratio between the soil and the extracting liquid and a short period of extraction of a few minutes. These methods have been successful on soils that are not calcareous or very high in exchangeable calcium or calcium sulphate, like many of the fen peats.

One of these extracting solutions is M/2 acetic acid buffered with M/2 sodium acetate, first used by Morgan for rapid soil analysis, and it has proved better than citric or lactic acid where iron phosphates are present in the soil, for these are dissolved less readily by acetic acid at *p*H 4·8, which is the *p*H value of the buffer solution. Some of the extracting solutions, notably citric acid, extract organic matter from organic or peaty soils, and it has been found that for annual crops or where rapid growth is required the phosphate combined with the organic matter should be ignored, as it is commonly of low availability. In the early years of use of citric acid errors were sometimes made in estimating available phosphate owing to the inclusion of organic phosphates.

Organic matter

Methods for the determination of organic matter depend on an estimation of carbon—which may represent 95% of the organic carbon if the soil contains no fragments of charcoal, coal or partly burnt cinders. The figure for carbon may be used as such or converted to soil organic matter of average composition by multiplying the percentage of carbon by a factor of 1·724; this factor is fairly reliable in dealing with well aerated soils but is less satisfactory with peats and acid heathlands. The amount of organic carbon that can be estimated at a time is small, and for organic or peaty soils a fraction of a gramme of soil may have to be taken. This is one instance in routine soil work where uniformity in amount of soil is not possible. What is required is uniformity in amount of organic matter, and this imposes limits on the number of determinations an operator can do in a day and demands more care in preparing and weighing the sample for analysis.

Organic matter levels in soils are determined by soil conditions, such as texture, moisture, aeration, temperature and acidity, and by the kind of farming and cultivations. Organic matter is derived from plant residues, and the better the growing conditions are for crops the greater are the residues that they leave in the soil. Soil conditions that favour growth also favour biological activity that breaks down organic matter in the soil. In general, organic matter levels fall in arable soils to 2–3%; if the decline continues, the return of crop residues may be diminishing owing to partial destruction of roots by soil pathogens or to adverse physical conditions developing in the soil. Where patchiness begins to develop in crops on wholly arable farms, it is often useful to examine the physical state of the soil, the development and healthiness of crop roots, and the level of organic matter. Restoration of a soil to a better physical condition and higher productivity may not depend simply on the return of more organic matter, for a rest from the type of cropping and farming that has been practised may be needed. A change to ley farming—if it is possible on economic grounds—will provide this rest, improve physical conditions and the return of organic matter, and probably reduce the number of pathogens; but if soil deterioration is advanced the ley will be slower in having a beneficial effect and much improvement may not be apparent in the first two years.

Nitrogen

The total nitrogen in soils may be determined as a guide to the nature of the organic matter and whether more than the usual amount of nitrogen should be added in fertilizers. The determination cannot be put on a rapid routine basis and, like that of organic matter, should only be done where a falling off in crop performance appears to be linked with organic matter and availability of nitrogen. A common ratio of carbon to nitrogen (C/N) in soils is 10/1 or of organic matter to nitrogen (OM/N) 17/1. Wider ratios than these may indicate recent substantial additions of strawy or fibrous material low in nitrogen to the soil, and additional nitrogen will then be needed to maintain an adequate supply of available nitrogen to crops. Narrower ratios indicate substantial additions of organic matter from heavily manured intensively stocked leys or from legumes, in which circumstances available nitrogen may be released at a high rate when the soil is returned to arable cultivation. Instances of this kind occur where the cereal crops following, even the stiff-strawed varieties, should receive much less nitrogen than is normally applied to them. Soil analysis has been used to recognize the condition but consideration of the husbandry is mostly all that is necessary.

Attempts have been made to judge the rate of release of nitrate into glasshouse soils from organic matter, using organic matter-nitrogen ratios and the total amount of organic matter as the means of assessment. When straw mulches were used the straw walls placed at close intervals in glasshouse soils to assist entry of water, a degree of nitrogen deficiency did at times arise owing to the use of ammonium and nitrate by soil organisms in breaking down the straw. Soil analysis of the above kind confirmed a diagnosis of nitrogen deficiency which was apparent from the appearance of the crop and was to be expected from the heavy rate at which straw had been applied. It remains an indicator of possibilities which should be as well or better known from the treatment that the soil has received. It is crude in its application, but more refined use is hardly possible because biological activity, which determines nitrate release, is affected considerably and for a long time by partial sterilization of glasshouse soils.

From time to time attempts are made to assess the availability of nitrogen in soils, from determinations of ammonium and nitrate and the rate at which these are produced when a soil is moistened and incubated at a temperature of 20–30° C. There are two main difficulties in applying these techniques to field conditions: (1) the climatic conditions of temperature and rainfall which largely control biological activity cannot be predicted beforehand, and (2) the lower horizons of soils may contain substantial amounts of nitrate which have been carried down and dispersed by drainage water and are available to roots that reach them. The drainage conditions can be assessed from visual examination of the soil profile, and those familiar with the technique will know the wide range of conditions that can be found. The distribution of nitrate will depend on drainage conditions, the amount of water passing through the soil—whether down cracks or through the body of the soil—and the amount of nitrate present in the top soil as a result of biological activity or addition of nitrogenous fertilizer prior to the entry and passage downwards of the water.

The situation is not one that can be resolved by soil analysis alone, even if detailed sampling of the soil to the depth were possible, but in a rough way it can be said that much rain in autumn may carry nitrate below the immediate root range of autumn-sown crops or grass, and that after a wet winter nitrate will be very low throughout the root range in most soil profiles. Some adjustment to nitrogenous manuring of crops may be made in the spring, depending on whether the previous autumn and winter were wet or dry.

Determinations of ammonia, ammonium and nitrate are sometimes made on soils that have been sterilized, and toxicity symptoms have arisen in seedlings that have been subsequently grown on them. In these instances, soil analysis has useful diagnostic value.

Sulphur, Chloride and Trace Elements

Sulphur occurs in organic combination in soil organic matter and as sulphate, the form available to crops, mainly combined with calcium. Sulphate is released by biological breakdown of organic matter and is distributed in soils by drainage water and water movement. Accumulations of calcium sulphate occur in some soils from mineral sources. The problem of estimating the amount of sulphate available to crops is similar to that of estimating nitrate, except that the movement of sulphate is checked by the relatively low solubility of the calcium salt.

No instances of sulphur deficiency have been reported in the U.K., although crops may remove from 10–40 lb. sulphur per acre. Sulphur is contained in the fumes and smokes from town and industrial areas and it is believed that most areas in this country receive adequate sulphur from these sources. It is also contained in the fertilizers ammonium sulphate and superphosphate and in organic manures and farmyard manure; 1 cwt ammonium sulphate contains about 25 lb. sulphur and 1 cwt superphosphate about 10 lb. Soil analysis has been used from time to time to assess sulphate levels in likely areas of sulphur deficiency, but very little data has been collected. Should further investigation become necessary, rapid methods of detecting very small amounts of sulphate will be needed.

The problem of estimation of a freely mobile material, like nitrate, in soils arose with chloride on a considerable scale after the coastal floods of 1953. Here the problem was to locate and predict the movement of toxic amounts of chloride; a practical answer was to determine the chloride content at 0–6, 6–12, and 12–18 in. in the soil and to estimate the risk to crops from the levels found, the time of the year when the crop was to be sown, the drainage conditions and the salt tolerance of the crop.

Because of their importance to crops in areas where deficiencies arise, methods of estimation of some of the trace elements in soils have come into use. Fortunately, the deficiency symptoms shown by crops have been established, providing a means of recognizing the elements concerned in the first instance. Soil analysis is being used to assess levels of availability of trace elements in deficient soils and then to examine soils suspected of being near deficiency level. It will be established first that a deficiency is associated with certain soil conditions and not with others, and the probable extent of the deficiency in a region will then be predicted from knowledge of the distribution of soil types and soil conditions. Methods of analysis will be based on the chemistry of the trace element, the chemistry of soils, and the analytical techniques that are available. Boron, copper and cobalt deficiencies are being examined with some success on these lines, but manganese and iron deficiencies, which depend on certain soil conditions rather than on lack of these elements in soils, have not as yet yielded to soil analysis. Where excess availability of trace elements is a problem, as can happen with manganese after a soil has been sterilized, or through contamination of a soil with an industrial waste, soil analysis is better able to ascertain the cause and has useful diagnostic value.

SOILING OR ZERO GRAZING

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In the search for ways of making the best use of grass and forage crops attention is again being given to the old practice of soiling under the new name "zero grazing." The authors of this article review the subject and discuss the implications of their own experiments. They conclude that zero grazing has many advantages in the feeding and management of cattle and can increase production and cash returns in various farming systems.

Renewed interest in now being taken in the age-old practice of feeding cut crops to housed stock. Soiling, as the process was called, was in common use among dairy farmers for well over 100 years, and although it has dropped out of practice it still survives under special conditions. It is, for example, widespread in Switzerland, and in parts of South Germany where the strip system of agriculture still obtains the cattle must perforce be fed indoors on green crops. In Great Britain at the beginning of this century soiling was in particularly high favour with town and suburban dairies, for these received a premium of up to 25% on the price of milk in summer. But with rising costs of labour and falling prices for milk it began to lose in popularity, and in 1933, when the newly formed Milk Marketing Board provided a level price for milk, thus removing the premium held by producer-retailers, the system was almost completely abandoned. There are today only a few milk producers for whom grass crops are grown under contract and cut and carried to feed green, while manure is carried back to the farm.

The return of the system has been due to several factors, not the least of which has been the reduction in the cost of cutting and carting made possible by the development of modern machinery, especially the forage-harvester. Another fundamental factor has been the great advance that has taken place in the utilization of grassland, applying the term in its widest sense to include all forage crops grown for farm animals. Thus, extensive grazing with its difficulties of control of the herbage at the optimal state for grazing has been replaced by rotational grazing on smaller areas. With the advent of the nitrogenous manuring of pastures this reached its extreme form in the Hohenheim system which made use of small fenced enclosures, allowing greater control of grazing; these were heavily manured and rotationally grazed, any surplus being cut for hay or silage at periods of maximum production off areas later brought back into the grazing cycle. Such a procedure involved considerable expense in fencing and watering.

A great advance was made possible by the introduction of the electric fence, for the herbage could then be used much more efficiently. In the Netherlands De Geus [11], using an electric fence, found strip grazing to have a 10–20% greater efficiency in use of herbage than rotational grazing. In England Procter *et al.* [27] also compared strip grazing using an electric fence with efficient and heavy rotational grazing: the strip-grazed area produced, per acre, 171 grazing days, 4870 lb. of milk and 2331 lb. of starch equivalent, whereas the control area gave only 129 grazing days, 3869 lb. of milk and 1808 lb. of starch equivalent per acre, i.e. an increase of about 25% in favour of strip grazing. In another trial in England Holmes *et al.* [18] recorded a production per acre from strip grazing of 632 lb. digestible crude protein and 4316 lb. of starch equivalent as against 486 lb. and 3371 lb. respectively from rotational grazing—a gain of 25–30%.

Despite the control of grazing made possible by the use of an electric fence there was still some degree of waste, and it is in the hope of reducing this loss that the concept of cutting the herbage and feeding it to housed stock has again come to the fore. The modern concern is chiefly with the feeding of cut grass, and because this does not entail grazing the name "zero grazing" has been coined for the technique in the U.S.A. This, however, is nothing more than the soiling process applied to pastures, and, as annual forage crops are widely used in the southern states of the U.S.A., the original and more comprehensive term is preferable.

It is the special purpose of this paper to describe experiments on zero grazing now being carried out by the writers at the Edinburgh School of Agriculture and to discuss the results so far obtained, but the opportunity is taken to review the whole subject of soiling from the earliest times to the present day.

EARLY EXPERIENCE OF SOILING

The procedure in former days has been described to the senior author by a friend in the Edinburgh district who remembers as a young man cutting the grass for the cows. A load of 30 cwt. was cut early in the morning by scythe at the rate of 2–3 tons per hour. The cows received three 2-stone feeds daily, a total of around 84 lb. of grass per cow, mostly a mixture of Italian ryegrass and clover. In addition, 2½ gallons of wet brewers' grains were fed with treacle at the rate of 1 gallon for every 100 gallons of the wet grains, plus bean or pease meal and some salt, the whole being fed as a gruel; an extra allowance of 6–8 gallons of water was given per cow in warm weather. It is interesting to reflect that he did not find the work excessive, despite the fact that all the water had to be carried to the cows in pails.

Another friend from the Perth district recalls growing strips of grass for town dairymen, who came out and cut the grass to cart away for feeding. Here also scything was the more popular method of cutting; the mower, though often used, was not satisfactory for dealing with heavy crops, which the scythe left in a better condition for picking up and loading.

The earliest reference in the literature, a paper by Caw [9] in 1812, deals with cows soiled on clover on a farm in Perthshire from mid-June to mid-September. Advantages claimed by Caw for soiling over grazing were:

1. A large and profitable stock of bestial was kept at a comparatively small expense.
2. An extra supply of rich manure was obtained.
3. Pasturage, on a farm ill adapted for it, was dispensed with.
4. Having one-half of the farm in white crop gave a better return and more ample means for the production of manure.
5. The land was kept clean and in good heart under a severe mode of cropping by introducing a fallow or a drilled green crop every fourth year, and by dunging.

A financial advantage was claimed for soiling though no mention was made of the costs.

In Scotland over a century ago Adam [1] carried out a trial with three groups each of four 2-year-old Aberdeen Angus × Shorthorn heifers. Group A were grazed on a first-year ryegrass and clover sward; Group B were fed the green cut crop in stalls; Group C were fed indoors with green cut grass plus oats and cake. The grazed group used 3½ acres and left no profit. The soiled groups each used the produce of 1½ acres, and that on grass alone made a profit of £3 16s. 8d., while that with the extra feed made £8 8s. 2d. Templeton [31], a contemporary of Adam, compared soiling under open yards and stalls with grazing. Using 3-year-old Galloways, he concluded that soiling was better than pasturing and the open yard better than the stall. Spearing [28] in England recommended keeping cows indoors through the day to avoid flies, feeding lucerne and sainfoin cut green.

Much early work has also been done in the U.S.A. Henry and Morrison [15] in Wisconsin quote the work of Josiah Quincy, who wrote in 1820 about his experience dating back to 1814. Quincy maintained 20 cows in stalls, allowing exercise in an open yard, on crops from 17 acres of land where 50 acres had been needed when the cows were grazing; this result was, of course, not obtained from grassland herbage alone. They also report the work of Henry (1885), who kept 3 cows on 3·7 acres of pasture for 122 days in summer and maintained 3 others in stall and yard for the same period by feeding green clover, green maize and oats, cut from 1·7 acres on which a total of 44,835 lb. of green forage was produced. Yields of milk and butterfat in lb./acre were 4782 and 195 respectively from soiling crops, and 1780 and 82 from pasture.

Otis [25] in Kansas found that to produce the roughage for a cow for 144 days required 0·71 acre of soiling crops, half of it in lucerne, as compared with 3·6 acres of a mixed pasture.

Peer in 1881 [26] wrote a book on soiling and in 1900 enlarged it to cover ensilage, which he calls "winter soiling." On a 100-acre farm he supported the equivalent of 36 head of cattle on 30 acres, cropped the remaining 70 acres with cash crops, and produced sufficient manure for all purposes. His basic reason for starting soiling was to avoid the cost of fencing and the loss of land that fencing entails; but he emphasizes that account must also be taken of the loss of potential nutrients caused by cattle trampling or lying on the herbage, and above all by selective grazing which leaves the pasture progressively less valuable. This is a finding that modern work fully confirms. Peer estimated the loss of potential value due to these causes at anything from one-third to one-half. A similar figure for Switzerland is quoted by Grandjean [12], who estimated the yield of starch equivalent from cut herbage and measured the output as obtained in the milk and herbage used by dairy cows for their maintenance in the same field; the grazing herd used only 48% of the available nutrients in 1930 and 55% in 1931. In a second set of trials [13], by improving the management, the utilization rose to 78% in 1934 and 66% in 1935.

Stewart [29] in America found 50 acres of soilage to be equivalent to 125 acres under grazing systems and discusses the financial benefits obtained. He also estimated that the fences on a 300-acre farm covered 5 acres of land.

Several authors have compared soiling with the feeding of silage. Lane [21] in 1902 reports that the average yield over 6 years from feeding a soiling crop from May to October and silage from November to April was to the advantage of soiling, but this is an unsatisfactory basis for comparison; Billings [5] in 1904 obtained similar results, both authors being from New Jersey, but later [6] he compared silage fed in the summer with soiling crops and found no differences between the two types of ration. This conclusion was also reached by workers in Wisconsin [36]. Foreman *et al.* [10] have reported briefly on the relative value of green cut and ensiled lucerne.

In Britain the main work on soiling, using arable crops entirely, was carried out by Brown [8] at Harper Adams Agricultural College. He found that cows on green cut crops milked well, maintained their condition, held to the bull, and carried good calves. In these experiments no grass was fed, cut or grazed. In 1925 the University of Leeds [2] published a review of four years' soiling of cattle on a farm in Yorkshire. A scheme utilizing a rotation of crops, including grass, was put into practice, but costs of production proved to be greater with soiling than with grazing.

RECENT EXPERIMENTS

Coming to more recent times, an experiment was carried out by the National Institute for Research in Dairying in 1948 [3]. The object was to contrast the value of spring grass cut and fed indoors and grazed. Two lots each of 7 cows were selected. During the first three weeks—a critical period—the average weekly increase in milk was 7·68 lb. from the grazed cows and 5·66 lb. from cows fed on cut grass in a covered yard—a difference that was not statistically significant. The amount eaten by the grazed cows was not measurable, but the indoor group ate as much as 150 lb. per cow on some days. Composition of the milk was satisfactory.

It is during the last five years that the evaluation of cut grass has become a matter of more accurate measurement. In California Ittner *et al.* [19] compared rotational grazing with strip grazing, green soiling, and soiling with wilted herbage. They worked with beef cattle on lucerne. The results, summarized in Table I, show a marked advantage in favour of green soiling. The feeding of wilted lucerne gave curiously low values, probably owing to a marked loss of leaf and finer stem during the handling of the wilted crop. Since the daily gains in all four groups are similar, the increase due to green soiling must be a direct reflection of the greater total weight of crop offered to the animals. A small amount of oat hay was fed daily to prevent bloat, and this was allowed for in calculating the amount of beef produced per acre.

In subsequent experiments by these workers [24] the feeding of wilted lucerne was replaced by feeding hay made from material at the same stage of growth as that cut for soiling. At two centres groups of 9–10 steers were fed for 155 and 132 days respectively. The rotational plots were grazed at intervals of 7 and 5 days and strip grazing was also practised, though in the first experiment it is called 1-day rotational grazing. Table II gives the results. Strip grazing in these experiments showed little advantage over rotational grazing; feeding hay gave better results, and soiling still better.

Stone [30] in 1959 has reviewed results obtained in the southern U.S.A., about half of his references being to unpublished work sent to him in response to enquiry. The position was not always directly referable to grassland, since many other crops were used to feed dairy cows, but these would normally be grazed, so the results do show the relative values of a crop when grazed or cut.

TABLE I

COMPARISON OF SOILING AND GRAZING TECHNIQUES USING LUCERNE FED TO STEERS IN CALIFORNIA.

(Data from Ittner *et al.* [19])

Criterion	Rotational grazing	Strip grazing	Green soiling	Wilted soiling
No. of Steers ..	10	10	10	10
Days on test ..	168	168	168	168
Av. daily gain (lb.)	1·80	1·90	1·92	1·78
Beef prod. (lb./ac.)	414	580	704	568
Relative value ..	100	139	169	136

TABLE II

COMPARISON OF SOILING, HAYING AND GRAZING TECHNIQUES USING LUCERNE FED TO STEERS AT TWO CENTRES IN CALIFORNIA.

(Data from Meyer *et al.* [24])

Criterion	Rotational grazing		Strip grazing		Haying		Soiling	
	1	2	1	2	1	2	1	2
Av. daily gain (lb.) . .	1·94	1·79	1·70	1·64	1·67	1·45	1·80	1·73
Beef prod. (lb./ac.) . .	525	689	539	739	576	856	678	1080
Relative value	100	100	103	107	111	124	129	157

Stone reports that in Louisiana Ellzey obtained 400 lb. more milk per acre by soiling. Data from Mississippi also showed that a given acre produced more milk by this practice. Tennessee trials showed an increase of 123% of milk by soiling compared to strip grazing using lucerne, and of 17% using Sudan grass. Soiling also made a larger area of excess lucerne available for ensilage. Owen *et al.* in Mississippi found soiling to have a 9% advantage over strip grazing and one of 47% over rotational grazing. Ellzey put the increased carrying capacity due to soiling at 71%. Both Owen and Ellzey report that cows made greater liveweight gains when fed on cut grass than they did when grazed. Stone in his own experiments used pearl millet as the forage crop and found soiling to be superior to grazing. On the other hand, two reports received by Stone from Tennessee and Beltsville were not in favour of soiling grass.

Kennedy *et al.* [20] at Cornell, over a two-year period, got better results from rotational grazing than from strip grazing or green soiling, but large quantities of excess forage were taken from the cut areas; final evaluation awaits fuller data.

Larsen [22] reported on two years' work at Wisconsin in which stored feed, green feeding, and grazing of pasture crops were compared. The results (Table III) showed that the stored grass treatment produced most milk per acre, but green feeding was more satisfactory than strip grazing.

Blaser *et al.* [7] state: "Reports from many experiments show that acre yields from green soiling are generally higher than the yields from good grazing management. The high yields from soiling may be attributed to the efficient herbage utilization (losses due to fouling and trampling are nil); more advanced stage of growth when harvested, which adds to the dry matter yields; and the elimination of injurious effects of the animals on the soil and plants." To these advantages Stone [30] adds: distant fields can be brought into the cycle; intake of nutrients is level by day and night; the period of green food production per acre is prolonged; and the procedure is a good research tool. He stresses the value of modern machinery in making it easy to harvest the crop and to ensile any surplus. McCutcheon [23] speaking as an engineer, does the same and puts the main advantage of soiling as: increased production per animal; increased crop usage; better land use; simplified farm layout and fencing; and, a most valuable factor, a degree of bloat control not possible under conventional pasture systems.

The disadvantages according to Stone are that: only where herds are large can the equipment be afforded; there is a problem of manure disposal; no selection is possible by the animal; and the process is affected by topography. To the authors of this paper, however, absence of selectivity is a distinct advantage, for it gives a more standard daily diet than is the case where the animal is free to select what it wants and therefore eats the leafiest and most nutritious herbage first, with subsequent daily deterioration in quality of the feed.

TABLE III

COMPARISON OF SOILING WITH GRAZING USING GRASS FED TO DAIRY COWS IN WISCONSIN

(Data from Larsen [22])

Criterion	1955			1956		
	Stored feed	Green feed	Strip grazing	Stored feed	Green feed	Strip grazing
No. of cows . .	10·9	11	11	12	12	11·5
Days in pasture . .	118	118	118	108	108	108
Milk prod. (lb./ac.)	5,471	4,184	3,166	4,952	5,222	3,833
Livewt. change (lb.)	+11·8	+31·7	−35·8	+102	+116	+87
Use of avail. D.M. (%)	90	97	76	86	99	71

It was against this background that the decision was made to carry out an experiment on green pasture soiling at the Edinburgh School of Agriculture.

TRIALS AT THE EDINBURGH SCHOOL OF AGRICULTURE

To determine the possibilities of zero grazing under present-day conditions of machinery and prices in Great Britain, a trial comparing the system with strip grazing was laid down in 1956 and repeated in 1957 and 1958.

The animals used were pure-bred Ayrshire and Friesian cows from the dairy herd of the Edinburgh School of Agriculture. The zero-grazed group of 40–45 cows, with 36 in milk, was housed in a semi-open loose-housing yard having along one side a trough into which the grass was put (Figures 2, 4). These animals were milked in a 4-stall, 4-unit milking parlour. The strip-grazed animals were milked in a cowshed. The time of calving of the groups varied throughout the year but within each was a number of animals which calved at a similar time.

The zero-grazed animals were fed to grass appetite and concentrates were given only to cows yielding over 4½ gallons (reduced to 2 gallons in September), to newly calved cows and, during the early summer months, to some animals as a precaution against hypomagnesaemia. The strip-grazed animals were confined to paddocks of approximately 4 acres. No backfence was employed, but every effort was made to alternate grazing and cutting so that the contaminating effect of dungpats was largely dissipated before the next grazing. Concentrates were fed at the same rate as to the zero-grazed group. The grass areas used were not the same but care was taken to duplicate the type of material. The aim was to use grass to the maximum and to keep the concentrates fed to a minimum.

The zero-grazed group was fed twice each day with freshly cut grass. The bulk of the material was cut by a flail harvester (Figure 1), a small amount being handled by gang-mower. The first feed was given at 8 a.m. and a second load of grass was then cut and laid alongside the trough to be fed at 1.30 p.m. Any residue in the trough was weighed back. All material was weighed over a large platform weighbridge (Figure 5).

Quality of the grass fed and grazed was determined from samples taken three times each week and analyses made of the dry matter and protein. The herbage offered to strip-grazing cows was sampled by cutting small areas at random. The milk was weighed at each milking and samples for solids-not-fat and fat determinations were taken each Monday morning and evening. All the cows were artificially inseminated. The lying area of the cows was bedded daily, mainly with straw.

Results

Results from the 1957 and 1958 replicates of this trial may be considered in two ways, as summarized in Table IV A and B. Production of the complete group of animals is given in Table IV A. The group includes cows at various stages of lactation and does not allow of a comparison of the milk production figures. It does, however, compare the stocking rate of two systems with a large number of animals.

The total milk production of the two groups is given and the value of the grass is assessed by deducting the assumed milk-production value of the concentrates (1 gal. milk/4 lb. concentrates) to give a net milk production from grass. Milk production from the strip-grazed group is higher than that from the zero-grazed group, but much of this can be accounted for by differences in stage of lactation and age of the animal. Acreage requirement per cow, milk production per acre and cow grazing days per acre are also given. The increase

TABLE IV

PRODUCTION OF MILK FROM STRIP-GRAZED AND ZERO-GRAZED COWS DURING THE 2-YEAR PERIOD

4th April–10th October 1957 = 189 days
1st May–8th October 1958 = 160 days

Criterion	Strip-grazed	Zero-grazed
A. ALL COWS		
No. of cows . .	36	36·6
Total milk production (lb.)	188,773	156,086
Concentrates fed (cwt.) . .	139	95
Total milk from grass (lb.)	149,200	125,514
Av. milk from grass (lb.) . .	23·6	18·8
Total acreage . .	27·64	25·91
Acreage/head . .	0·77	0·7
Milk/acre (lb.) . .	5,275	4,782
Grazing days/acre . .	225	243
B. COWS CALVED IN LATE SPRING		
No. of cows . .	17	17
Total milk production (lb.)	98,555	80,254
Total milk from grass (lb.)	82,161	74,600
Av. milk from grass (lb.) . .	27·9	23·7

in the number of cow grazing days due to zero grazing was 7·8% in 1957 and 6·4% in 1958. The number of grazing days per acre was higher in 1958, 233 and 248 for strip-grazed and zero-grazed groups respectively, compared with 217 and 238 in 1957. Stock-carrying capacity during the 160-day period in 1958 of 0·64 acre/cow and 0·68 acre/cow for zero-grazed and strip-grazed groups respectively was higher than in 1957 when it was 0·77 acre/cow and 0·87 acre/cow in a 189-day period, probably because higher rainfall in the 1958 season resulted in a greater growth of grass.

Table IV B gives the results for a restricted number of animals within the two groups; these animals calved during the late spring and represent two comparable lots which milked during the summer. Daily production per cow was higher in the strip-grazed group by 4½ lb. in 1957 and 3·7 lb. in 1958. Table V shows that the initial yield was higher in the strip-grazed group. The persistency of milk production in each group was measured by the ratio of average yield to initial yield expressed as a percentage; this was the same in both cases.

The average analysis of the grass fed (Table VI) shows a marked difference in dry matter percentages between years and between groups. The digestible crude protein calculated from the crude protein content of the grass dry matter [35] was low in both years. The average daily intake by the zero-grazed cows of fresh grass, dry matter, starch equivalent and digestible crude protein is shown in Table VII; intake was lower in 1958, reducing the level of nutrition.

Quality of the milk produced by each group was satisfactory and no difference due to treatment was observed (Table VIII).

Breeding performance of the animals is given in Table IX. The low conception rate of 56% in 1958 improved to 85% at second service.

The straw requirement for bedding was very much greater with the zero-grazed group, daily requirements per cow in 1957 and 1958 amounted to 10·0 and 12·5 lb. respectively as against only 0·6 and 0·25 lb. for the strip-grazed group. The higher requirement in 1958 in the zero-grazed group was due to the wetter conditions prevalent during that year. Various clinical troubles appeared during the season but apart from foot troubles, which were more common in the strip-grazed group, there was no relationship to system.

Costs of operating a zero-grazing system are given in Table X with an estimate of the additional

TABLE V

AVERAGE YIELD OF STRIP-GRAZED AND ZERO-GRAZED GROUPS IN 1957 AND 1958 EXPRESSED AS A PERCENTAGE OF INITIAL YIELD

Group	1957		1958	
	Initial Yield (lb.)	Average Yield (%)	Initial Yield (lb.)	Average Yield (%)
Strip-grazed	45·6	72·1	48·2	64·3
Zero-grazed	33·8	76·0	41·1	62·0

TABLE VI

FEEDING VALUE OF GRASS FED TO STRIP-GRAZED AND ZERO-GRAZED COWS DURING SEASON

Criterion	Strip-grazed		Zero-grazed	
	1957	1958	1957	1958
Dry matter (%)	19·65	16·89	18·20	16·93
Starch equivalent	58·40	59·91	58·30	58·30
Dig. crude protein (%)	10·75	12·71	12·30	11·26

TABLE VII

AVERAGE DAILY INTAKE OF ZERO-GRAZED GROUP

Criterion	1957 (lb.)	1958 (lb.)
Fresh grass	145	136·6
Dry matter	26·4	24·6
Starch equivalent	15·44	12·44
Dig. crude protein	2·87	2·24

TABLE VIII

AVERAGE QUALITY OF MILK PRODUCED BY STRIP-GRAZED AND ZERO-GRAZED COWS

Criterion	Strip-grazed		Zero-grazed	
	1957	1958	1957	1958
Solids-not-fat (%)	8·88	8·72	8·92	8·76
Butterfat (%)	3·77	3·82	3·93	3·73

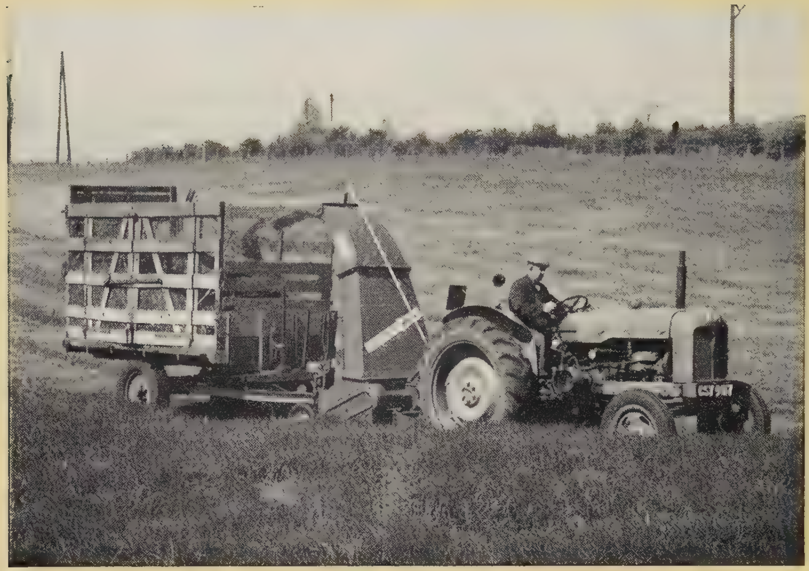

FIG. 1. Flail-type forage harvester cutting grass for zero grazing at Langhill Farm, Roslin.

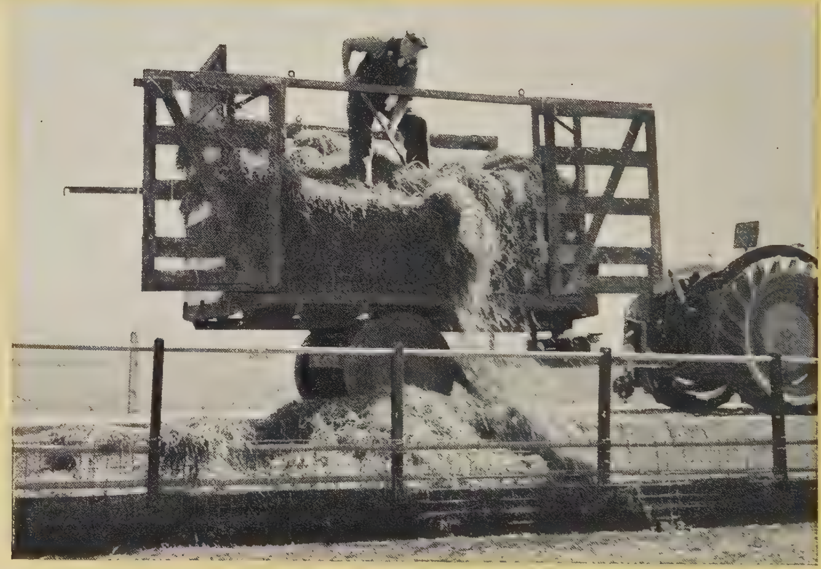

FIG. 2. Hand unloading of grass to dairy cows being zero grazed at Langhill Farm, Roslin.

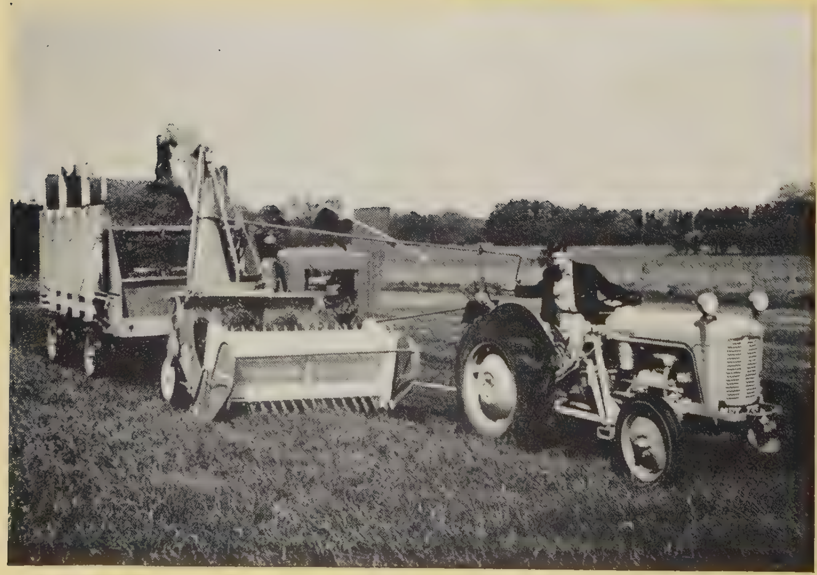

FIG. 3. Forage chopper being used in conjunction with a self-unloading trailer for zero grazing on a Berkshire farm.

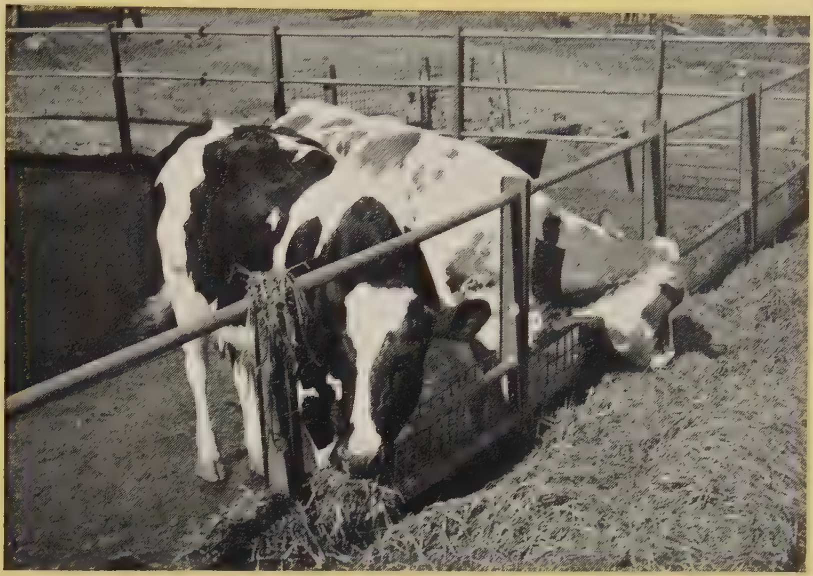

Fig. 4. Dairy cows zero grazing at Langhill Farm, Roslin.

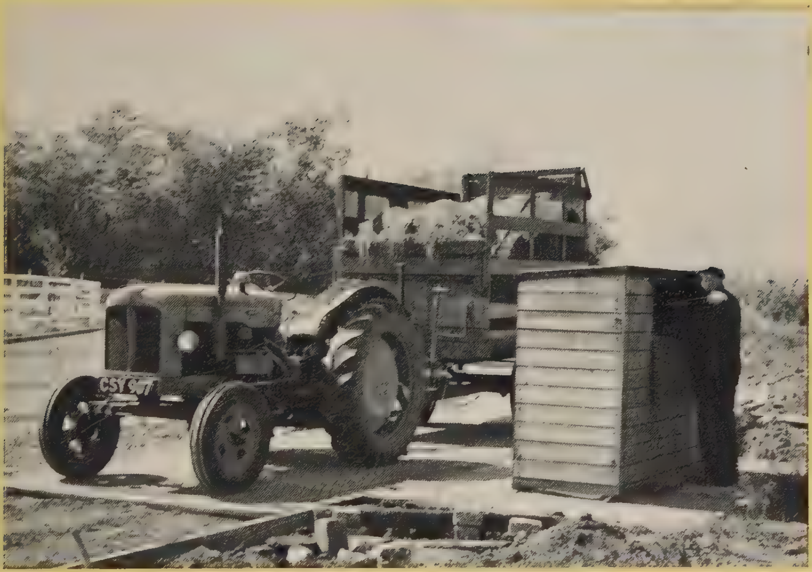

Fig. 5. Grass for zero grazing being weighed prior to feeding to cows at Langhill Farm, Roslin.

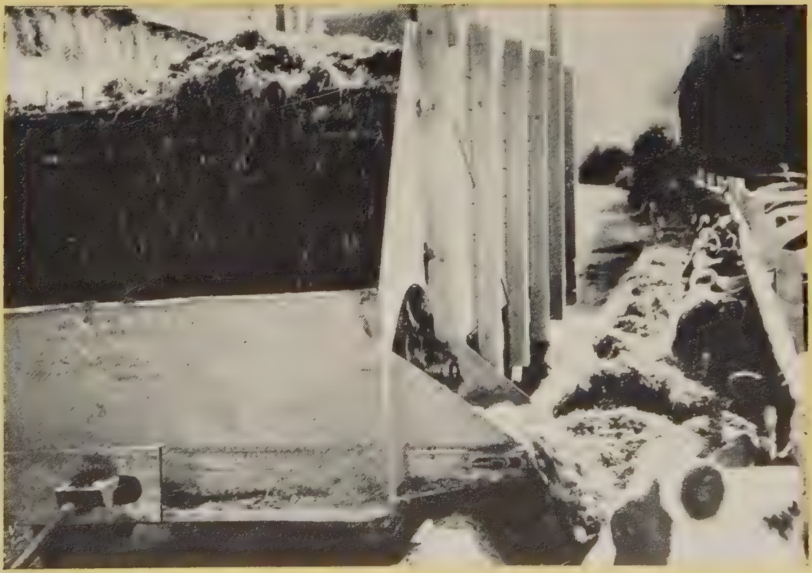

Fig. 6. An American type of self-unloading trailer in use on a Berkshire farm.

TABLE IX

BREEDING PERFORMANCE OF THE COWS BY ARTIFICIAL INSEMINATION

Year	No. of services		Conception after 1st service	
	Strip-grazed	Zero-grazed	Strip-grazed	Zero-grazed
1957	21	14	66·6%	72·1%
1958	20	17	56·0%	82·0%

TABLE XI

INITIAL LIVEWEIGHTS AND LIVEWEIGHT GAINS

Group	Initial Weight (lb.)		Gains in Weight (lb.)	
	1957	1958	1957	1958
Strip-grazed	1,156	1,118	145	84
Zero-grazed	1,200	1,286	173	111
Difference	44	68	28	27

cost over strip grazing when the number of cows is 45. Zero grazing showed an additional cost of £8 18s. per cow per season.

At the start of the feeding period liveweight of the zero-grazed cows was greater in both years than that of the strip-grazed cows; the average gains made by them were also higher (Table XI).

Discussion

The direct advantage of zero grazing over the strip-grazing management of cattle averaged 7·8% over the years 1957 and 1958. This was confined to stocking rate (Table IV: Acreage/head), as the design of the trial made accurate comparison of milk production impossible owing to the varying stage of lactation between groups. Because of this factor, however, stock-carrying capacity can be considered a more accurate assessment of the two systems of management. The comparison of two groups within the herd shows that persistency of lactation is similar under either system, though the initial level of milk production was lower in the zero-grazed animals. This is in agreement with American work [20]. It would therefore appear that animals can maintain their level of milk production equally well under either system.

TABLE X

DAILY COST OF ZERO GRAZING OVER STRIP GRAZING 45 COWS FOR A SEASON OF 180 DAYS

	£	s.	d.
GROSS ADDITIONAL COSTS			
Machinery			
Forage harvester @ 2s./ton of grass		6	0
Tractor: 2 hr. @ 3s./hr.		6	0
Trailer			6
Labour			
Feeding: Tractorman for 2½ hr. @ 4s./hr.		10	0
Cleaning and bedding: 1½ man hours		6	0
Bedding material			
Straw: 5 cwt. @ £5/ton	1	5	0
	£2	13	6
DEDUCTIONS			
Electric fencing costs @ £10 per annum		1	0
Labour saved in moving cows and fences		8	0
		9	0
NET ADDITIONAL COSTS			
Per day for 45 cows	2	4	6
Per cow for season	8	18	0
Per season for 45 cows	400	10	0

The advantage found in this trial for zero grazing is lower than is claimed by farmers practising the system, probably because the strip-grazed pastures had the high carrying capacity of 0·77 acre per cow. By alternating cutting and grazing wherever possible there was no problem from contamination of pastures; indeed, where grazing management is not at the same level, stocking might well be heavier owing to this factor alone. No evidence of the effect on level of yield was determined, but individual increases are unlikely to be obtained unless climatic conditions make sheltering of the cattle advantageous. The difference in the number of stock grazing days per acre between years is attributable to better growth of the grass in 1958 occasioned by the higher rainfall in that year.

The chief aim in this trial was to produce most of the milk from grass and to limit the use of concentrates to feeding of newly-calved cows and high yielders, and as a magnesium carrier. This resulted in lower average yields than would otherwise have been possible, but the policy was considered to be more justifiable economically than restricting grass intake and feeding extra concentrates and roughages. Grass can be fed at a cheaper rate per unit of dry matter than any other food, so that even for lower yielders there was no financial gain in restricting its intake and supplementing with low-quality roughage. During the summer months the low price of milk will not economically allow the heavy use of concentrates and there is no evidence to show that significantly higher milk yields are obtained by feeding them where the grass diet is adequate.

The daily intake of 24·6 lb. dry matter from grass in 1958 is unsatisfactory, and the figure of 26·4 lb. in 1957 is still low compared with estimates of 27–28 lb. on grazing [32] and of 31–34 lb. on zero grazing [20]. Some grass remained in the troughs in the early morning, and it is possible that this may have been refused owing to its unpalatability rather than to repletion of the animals. It would appear that economy in grass use could best be achieved by grouping the animals according to yield and varying the quantity of grass fed with the level of milk production. This can easily be carried out in most cases, at least two groups being practicable.

Quality of the grass was lower in both years than had been expected but a reasonable level of milk production was maintained. The difficulty of controlling grass quality with a machine as opposed to the animal can be reduced by using a machine of the gang-mower type, at least after the early summer flush of grass. It is, however, certain that cows do not require grass of the highest quality (i.e. 20–25% total crude protein) and the total grass production per acre is likely to be lower when cutting is done at the stage needed to procure it.

The breeding performance of cows under intensive zero-grazing conditions has often been questioned. The results here show conception at first service to be slightly higher than it is in animals at grass and also higher than average figures normally achieved by artificial insemination. Restriction of grazing activity, reduced concentrate supplementation, and heavy feeding of grass do not appear to have affected the conception rate.

The small liveweight gains made by the zero-grazed cows did not compensate for the saving in energy that, theoretically, would be achieved by not forcing the animals to graze. However, where strip grazing is carried out on pasture of a reasonable bulk, the increased energy requirement would not be much greater than in zero grazing and very much less than with animals on extensive grazing. Liveweights were satisfactory; on a visual assessment the zero-grazed cows always appeared to carry more flesh than the strip-grazed.

The increased requirement of zero grazing over conventional methods of grazing is both financial and managerial. Daily cutting and carting of grass to stock increases worry as to the availability of the herbage and reliability of machinery. The extra cost must be offset by an increased return, and this can be achieved if the price of the milk carries an adequate premium as it did in urban areas in Britain over thirty years ago and does at present in urban milk-sheds in the U.S.A.

The higher rate of stocking results in an increased production per acre, or the same stock can be kept on a smaller acreage and the surplus acres used for cash cropping. The financial return will therefore depend on the level of milk production per acre: with production at 500 gallons per acre a 10% increase in stocking would give 50 gallons more milk worth £6 10s.; at 300 gallons per acre the increase would be 30 gallons worth £4 10s. If the acres released by a more intensive rate of stocking are used for cash crops the financial benefit can be still greater.

In estimating the costs of zero grazing allowance was made for the straw used but not for the value of the dung, which would depend on the situation of the farm and probably be high in intensive market gardening areas and relatively low in grassland areas. Assuming that 1 ton of straw will produce 5 tons of dung, the cost of straw can be halved to give the net cost of the system. The extra dung may cause embarrassment on many all-grass farms, but on arable farms it can go on the plough land where the financial benefit is much greater. Moreover, the fact that animal residues are not returned to pastures does not appear to affect the production of dry matter from areas where the clover contribution to the sward is high [16, 33, 34], so that the dung can be reserved for use on high return crops.

The cost of operating a zero-grazing system will depend on:

1. Number of cows.
2. Method of operation.
3. Extent to which machinery is used for other purposes.
4. Amount of labour required.
5. Importance of grass as a milk-producing food in the feeding regime.

Machinery requirements will increase with the number of cows. With fewer than 20 cows the trailer into which the grass is cut can be taken into the yard and used as a self-feed rack [23]. When specialized machinery is used as many as 200 cows may be needed to make this economical. One group of American workers [17] questions the profitability of zero grazing with under 30 cows.

The ideal machinery combination is a direct-cut forage harvester and a self-unloading trailer (Figures 1, 3, 6), but this involves considerable capital and many cows to justify its specialized use. Hand-unloading from ordinary trailers (Figure 2) will reduce the machinery overheads, but increase the labour cost. A good lay-out of buildings and yard is essential for efficient machinery operation, yard cleaning and cow management. It is possible that controlled wilting would increase the dry matter content of the grasses and hence the total dry matter intake per animal, but this would complicate grass handling.

On small units of 40–50 cows the machinery used must be that involved in silage making, though at the risk of slowing down this process, as grass for soiling may be different from that for ensiling. A delay in silage making will result in an undesirable fall in digestibility of the material ensiled [4].

Employment of the dairy staff to cut, cart and feed the grass will reduce the labour cost, but make it difficult to provide the fresh material before 9.30 a.m. Moreover, either separate machinery must be available, thus increasing the overhead cost, or two separate staffs must use the same machinery, which is not ideal from the aspect of machinery maintenance. The provision of large trailers for feeding will reduce the number of loads required and the travelling time.

In the study described grass was the main item of diet; but grass can be of less importance where large amounts of supplementary foods are available, in which circumstances less would be required and labour and machinery costs could be reduced. Adoption of the practice would then depend largely on a favourable price relationship of milk and food.

Experience has shown that the green feed must be cut daily, so labour must be available at weekends. The possibility of cutting and feeding for five days and grazing for two has been investigated on a limited scale and found to have no significant effect on production [14].

THE PLACE OF ZERO GRAZING IN FARM ECONOMY

Such increases in production per acre as have been achieved by zero grazing can of course, often be reached by an improvement in grazing management. Nevertheless, zero grazing does result in an increased stocking rate and an intensification of the system of management; it also dispenses with the need for fences and piped water supplies, and provides shelter from heat and flies. Against these benefits must be weighed the increased requirements in labour, machinery and bedding which add to the cost of milk production. It must also be said that zero grazing goes against the present trend towards simplification of farming systems, though it would seem that the practice has a place in the farming economy in specific cases, such as those mentioned below.

1. *Large Herds*

On large dairy farms the management of pastures within easy walking distance of the milking point is often difficult. Milk yields are likely to suffer where cattle, particularly older animals with bad feet, have to walk long distances to a "day" pasture. But machinery is likely to be available for cutting and carting of the feed, and with a large number of cows the most efficient use can be made of this investment.

2. *Intensive Grass Management*

Where high yields of milk per acre are being obtained by conventional methods, further increases may be difficult to achieve. Zero grazing, however, is a likely way of increasing production, whether the herds be large or small.

3. *Shortage of Grass*

Since zero grazing gives complete control over the material fed to the cows, grass of high quality can be rationed out to animals whose milk production does not warrant a full intake. Accurate supplementation with concentrates is made more easy and with a saving of grass by the grouping of cows at different yield levels. In areas where bloat is prevalent, feeding of the dangerous herbage can be restricted and clinical cases avoided.

4. *Unsuitable Grazing Conditions*

Under wet conditions which do not allow the best use to be made of pasture by the grazing animal, machines will do less damage to the land than cattle. When fields cannot be used by the milking herd owing to distance from the buildings or the presence of main roads, cutting and feeding of the grass will allow them to be used by the most profitable type of stock-milking cows; the additional animal residues can be applied to these outlying fields, so that fertility is carried all round the farm and a system of ley-farming can be practised. Similar benefits are brought to land where lack of fences and piped water preclude grazing.

In areas where pasture production is liable to drop owing to unfavourable climatic conditions at certain times of the year, supplementary crops not suited to the grazing habits of animals can be used as succulent feeds, e.g. lucerne, vetches and maize. In the U.S.A. where climatic conditions are more extreme than in Britain crops of this nature are grown in rotation for cattle feeding. A recent development in the U.S.A. has been the use of silage as a succulent feed all the year round, no fresh green feed being given at all; this avoids any changes in feed and allows freedom to concentrate on the rapid ensilage of crops at the correct stage of growth.

5. *Beef Cattle*

On many farms young cattle of 6–15 months do not thrive well because pastures are wet and lush and climatic conditions are unfavourable. Housing of these cattle can then improve liveweight gains. Beef animals that are not finished by the end of the winter can be housed for a further period and fed grass, so reducing perhaps the check that animals receive on being turned out to graze and allowing them to be marketed when beef prices are high.

Results from America indicate that production per acre is higher when grass is fed than when it is grazed, though the individual gains were not significantly greater [19].

With beef cattle, the liveweight increases achieved can be cashed whenever prices are favourable, whereas milk has to be sold in summer when the lowest prices are ruling.

To sum up, the practice of zero grazing has many advantages to offer in the feeding and management of both dairy and beef cattle and, when used with the correct machinery and building lay-out, can increase production and financial returns in various farming systems.

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ADVANCES IN THE CONTROL OF CITRUS PESTS

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The complexity of citrus pest interrelationships has enforced caution on growers in their adoption of new control techniques and, while spectacular advances have been made in the field of application, very few organic pesticides have found acceptance. Each area has its own specific problems, necessitating an independent approach in which methods may range from the purely biological to the use of chemicals from the start of grove production.

One of the outstanding features of the modern war against plant pests is the rapidity with which advances are being made in evolving the means of destruction and methods for their application. Progress is to be seen in every field, but nowhere is it more evident than in the plantation industries, which have the organization and financial resources needed to exploit each advantage that science has to offer. All of them, indeed, contribute greatly to their own self-advancement by having their own research institutes and field experimental stations as well as the trade and technical journals by means of which new developments can be communicated without delay to the growers, technicians and merchants concerned. The citrus industry affords an excellent example of what is being achieved.

In comparison with such plantation crops as cotton, sugar cane and coffee, the area under citrus is small: the world total is only about $2\frac{3}{4}$ million acres, with more than one-third of this in the U.S.A. and the rest scattered over no fewer than 20 countries in both hemispheres, from Japan in the north to Argentina in the south. The major producing countries are listed below:

	Acres		*Acres*
U.S.A.	.. 995,500	Morocco	.. 96,400
Brazil	.. 261,100	Algeria	.. 87,700
Spain	.. 251,100	Greece	.. 82,300
Italy	.. 183,000	Turkey	.. 70,000
Mexico	.. 175,500	S. Africa	.. 57,500
Japan	.. 147,300	Australia	.. 57,100
Argentina	.. 139,600	Israel	.. 52,700
India	.. 136,000	Egypt	.. 43,700

But even in the smaller countries the industry is of considerable economic importance, and every effort is made to ensure high efficiency in production. This is particularly marked in plant protection, for the fruit and foliage of oranges, lemons, limes and other citrus crops are more than ordinarily subject to serious damage by pests.

THE PEST PROBLEMS

The pest problems on citrus are not only numerous but very complex and often serious (Figure 1). In every area at least one, and usually more, insect or mite species has reached economic pest status, but it is possible in this short paper to consider only some of the more important of these.

Rust Mites

Citrus rust mite, *Phyllocoptruta oleivora* Ashm, which belongs to the family *Eriophidae*, is present as a major economic pest in many areas. It is particularly severe where atmospheric humidity is high, e.g. Texas, Florida, Mexico, B.W.I., Venezuela and Japan. Rust mites are parthenogenic, and their straw-coloured, carrot-shaped bodies are just discernible under a hand lens. Conditions of high humidity increase the rate of breeding, and it is possible for a new generation to develop within 7–10 days.

The mites, which are mobile, are present on the tree the whole year round and prefer the more exposed locations, infecting leaves, fruit and new growth. Heavily infested leaves become dull and fall prematurely; damaged fruits are russeted, reduced in size, and ultimately only acceptable as low-grade produce at the processing plant. Recent detailed studies on the behaviour of the rust mite in relation to climatic variations over a period of years allow accurate local forecasting of periods of activity and abundance of the pest, thus enabling the grower to be more correct in the timing of chemical applications.

Sulphur and zineb are the only chemicals used commercially for the control of rust mite.

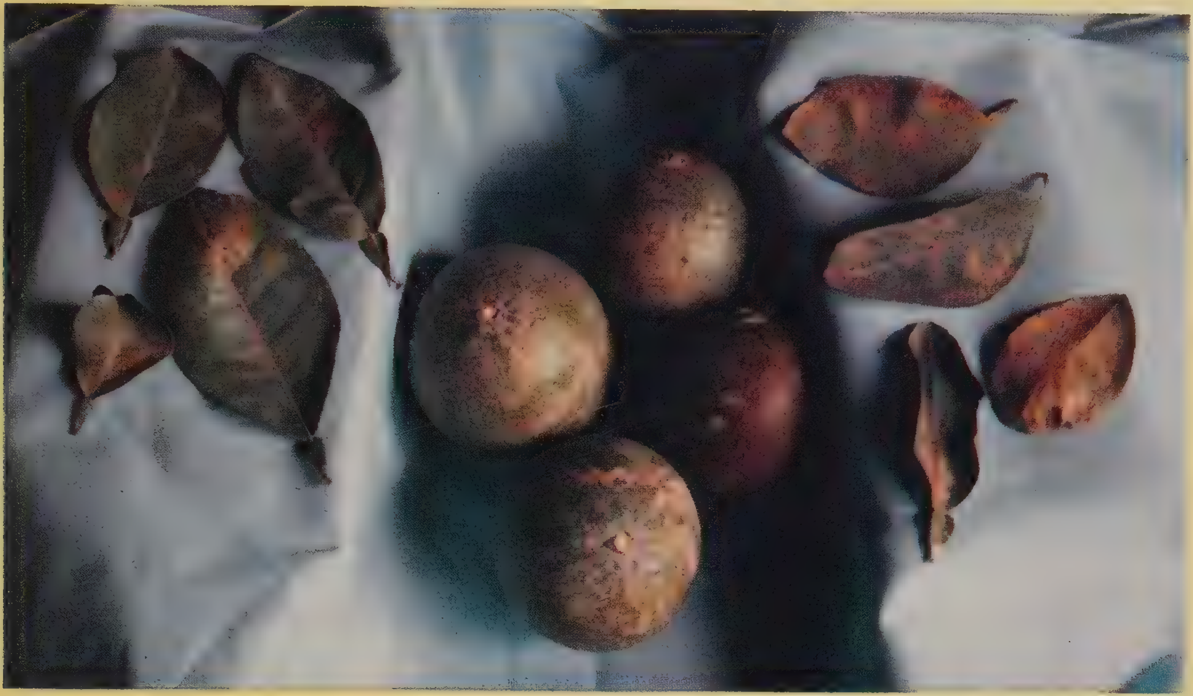

FIG. 1. Orange fruit and leaves severely infested with various species of scale insects and mites.

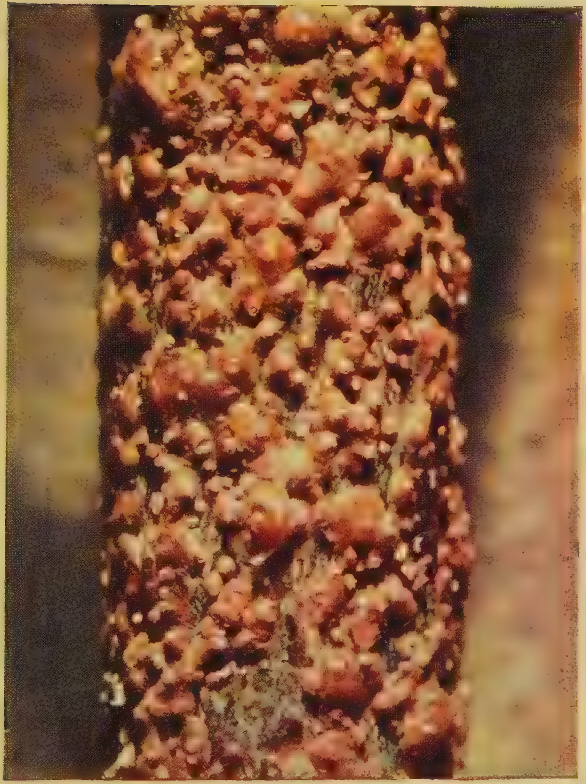

FIG. 2. California red scale. Heavy infestation on orange twig. (×6)

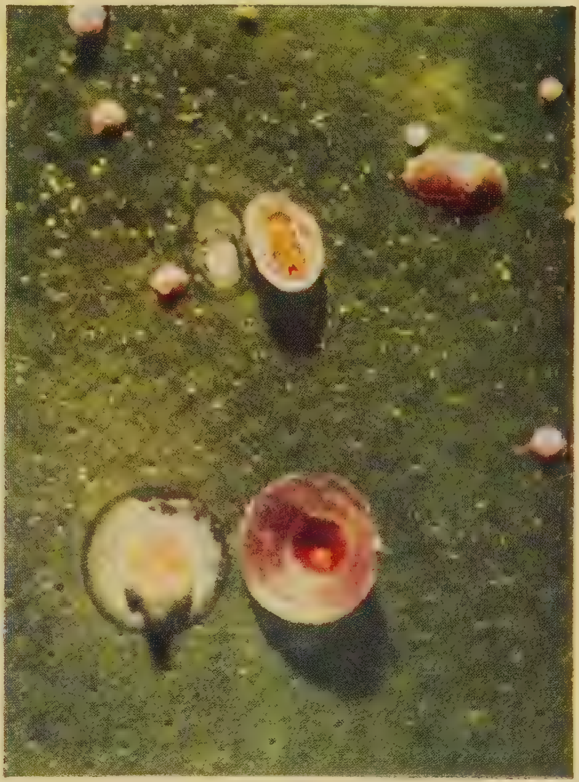

FIG. 3. California red scale. Below: Mature female with scale removed. Above: Male pupae. (×10)

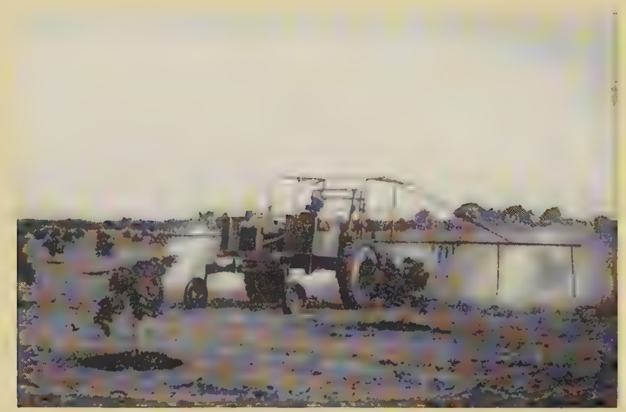

FIG. 4. A truck-mounted boom sprayer in use on a young citrus plantation.

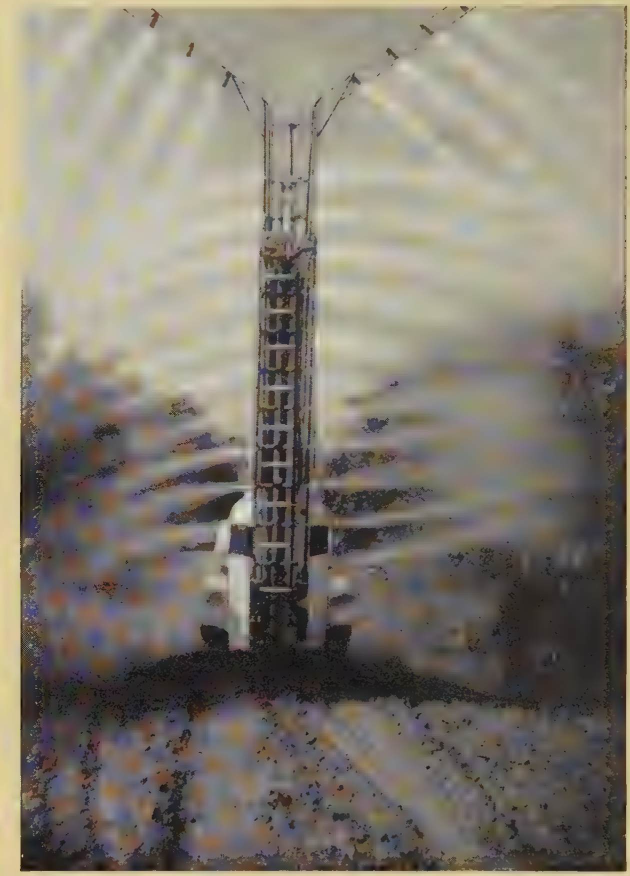

FIG. 7. The long arched double boom, spraying the sides and into the tops of trees in adjacent rows.

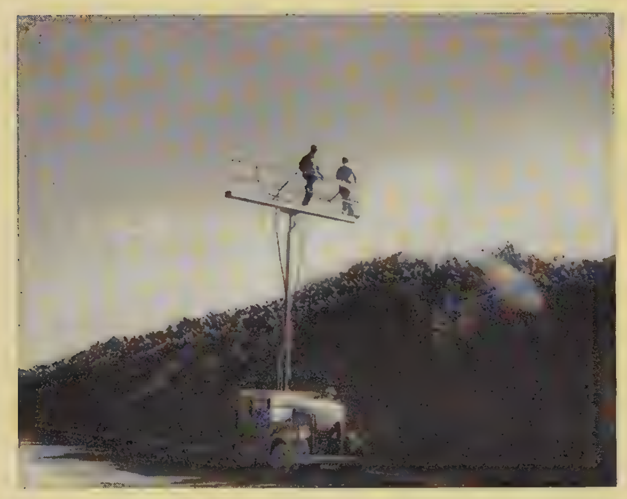

FIG. 5. Spraying by hand from a high adjustable platform.

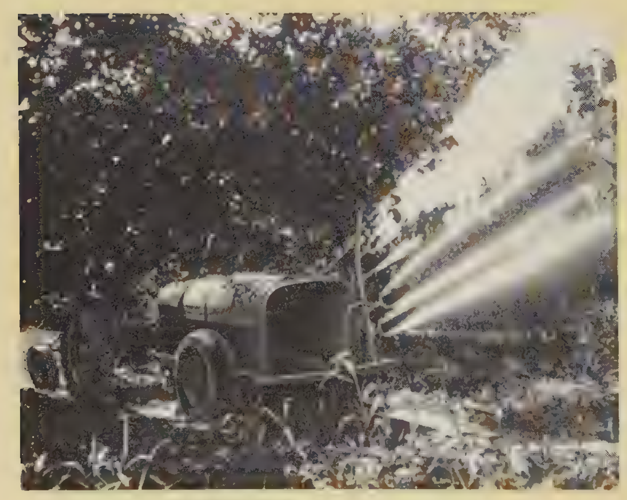

FIG. 6. Spraying mature citrus trees with an atomizing machine, the jets of which can be swung in all directions.

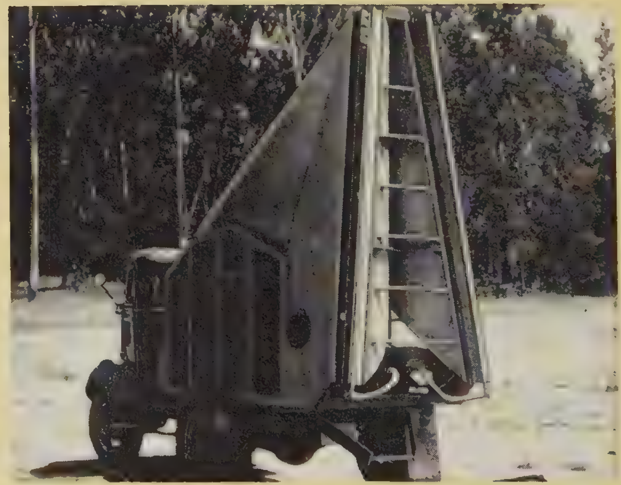

FIG. 8. A truck-mounted boom sprayer, showing how the booms are folded back when not in use.

Spider Mites

Spider mite species from the two families *Tetranychidae* and *Pseudoleptidae* form an important group of citrus pests. A very brief consideration of the mite problems in the U.S.A. will serve to illustrate the wide variations of feeding habits and damage which follow the activity of these pests.

The citrus red mite, *Paratetranychus citri* (McG.), is regarded as the major mite species in both California and Florida; it is unimportant in Texas and unknown in Arizona. The adults and nymphs feed on the fruit leaves and new twig growth and by means of their piercing mouth parts extract chlorophyll from the tissues; defoliation and poor-quality fruit result, and the trees lose condition. In Florida the six-spotted mite, *Tetranychus sexmaculatus* Ril., is also of importance; it differs from the red mite in attacking only the under surface of the leaves, causing characteristic yellow areas covered by very fine webbing.

The Texas red mite, *Anychus clarki*, McG., is the most important in humid Texas. It is very active, feeds almost solely on the upper surfaces of the leaves, and forms practically no webbing. Heavy feeding by this spider mite causes the leaf to develop a dull silvery-grey appearance.

Flat mites, *Brevipalpus* spp., and Yuma mites are the only types present in the hot dry citrus areas of Arizona. They attack the leaves and fruit and show great variation in population density, depending on seasonal temperature changes.

Sulphur dusts were used as a means of checking the activity of spider mites until the early 1920s, when refined petroleum oils became popular. Even to this day in some areas the value obtained from the dual purpose effect of a $1\frac{1}{2}$–2% oil spray on mites and scale is considered adequate to justify a continuation of this old method; where specific measures against spider must be taken, phosphorus chemicals, such as parathion and systox, are now commonly used. Vast quantities of parathion have been used in post-war years with considerable success, but it is now apparent that in some areas strains of phosphorus-resistant mites are becoming established. Other modern chemicals, such as Ovotran (*p*-chlorophenyl *p*-chlorobenzene sulphonate) and Aramite (2(*p-tert*.-butylphenoxy)-isopropyl 2′-chloroethyl sulphite), are occasionally recommended but they too are now raising resistance problems.

Scale Insects and Mealy Bugs

Scale insects and mealy bugs, which belong to the family *Coccidae*, are the most important and destructive pests of citrus. At least one and usually many species within this large group are present in every citrus area. The so-called "scale complex" varies widely from place to place, depending on environment as well as local spraying and cultural practices, and this general account can only indicate in a broad way the basic problems that face the citrus grower. These are discussed under the three main subdivisions of scale insects: armoured scales, soft or unarmoured scales, and mealy bugs.

The principal species in the armoured group is the Californian red scale, *Aonidiella auranti* Mas., which is without a doubt the most important citrus pest throughout the world. It is of great economic importance in U.S.A., Australia, South Africa, Brazil, Chile, Mexico and Argentina. The reproductive potential of each female is considerable, and 2–4 generations are possible each year. After birth the young "crawlers" remain for a few days under the protective scale covering of the female (Figure 3) prior to their moving out and establishing new areas of infestation. Any part of the tree, including leaves, fruit, twigs, branches and trunk, may be attacked. Severe infestations cause defoliation, fruit drop, or death of the twigs and branches (Figure 2). Purple scale, *Lepidosaphes beckii* New., has a wider distribution than Californian red scale but probably causes less damage, as it only becomes an economic pest in the more humid climates; it feeds on young leaves, fruit and wood and prefers the more shaded areas of the tree. In direct contrast the Florida red scale, *Chrysomphalus aonidium* Lin. (also known as the black scale in some Mediterranean areas), feeds on the leaves and fruit and favours the exposed portions of the tree; it will never become a major problem in the more arid areas. Chaff scale, *Parlatoria pergandii* Const., and Glover scale, *Lepidosaphes Gloverii* Pack, are common species which only develop on the more shaded portion of the tree.

As examples of the unarmoured scale group the black scale, *Saissetia oleae* Ber., and the soft brown scale, *Coccus hesperidum*, Lin., occur generally throughout the tropics and sub-tropics, citrus being just one of their host plants. They are both more or less active in all stages of their development and tend to move to areas of more succulent growth; by sucking the sap from the tissues they cause defoliation, fruit drop and dead wood. Sooty moulds always develop on the syrupy excretions produced by these insects. Cottony cushion scale, *Icerya purchasi* Mask, has a similar effect on citrus; it is conspicuously characterized by its long white egg sac, and so long as the balance of nature is not upset will be controlled by its parasite the vedalia beetle, *Rodolia cardinalis* Muls.

Mealy bugs, *Pseudococcus* spp., can be serious pests of citrus; but provided that the population of lady-birds and chalcid parasites is not disturbed by spraying or other adverse factors, these natural enemies can be relied upon to maintain infestations at very low levels.

To sum up, citrus growers have to contend with several species of scale, all of which may seriously affect their profits. Chemicals introduced in post-war years have tended to be too specific to meet the needs of this problem, and the majority of growers prefer the comparatively old-fashioned remedy of oil, which in spite of its limitations is effective in keeping down most of their scale enemies. The fear that some of the more powerful organic insecticides of recent discovery may upset the pest/predator relationship has also helped to foster a conservative approach to chemical control.

Fruit Flies

At least one species of fruit fly (family *Trypetidae*) attacks citrus and other fruits in all parts of the world except the U.S.A. The adults, which in many ways resemble those of the common house-fly, lay their eggs under the surface of various fruits. The larvae damage the fruit and when fully fed drop to the ground, pupate, and in time give rise to adults of the next generation. If conditions are favourable 10–15 generations can occur in a single season.

The six most important fruit flies affecting citrus are the Mediterranean fruit fly, *Ceratitis capitata* Wied.; the Mexican fruit fly, *Anastraepha ludens* Loew., of Central America; the Oriental fruit fly, *Dacus dorsalis* Hen., of the Pacific Islands; the South American fruit fly, *Anastrepha fratereulus* Wied., now widely distributed from Mexico to the Argentina; the Natal fruit fly, *Pterandrus rosa* Kar., common in South Africa; and the Queensland fruit fly, *Strumeta tryoni* Fro., predominant in Australia.

Only in 1929 and again in 1956 has the Mediterranean fruit fly managed to gain a positive foothold in the U.S.A. This country has been successful in preventing the establishment of fruit fly pests within its boundaries by imposing strict quarantine regulations, coupled with immediate blanket spraying of any area on which a single report of fruit fly damage is confirmed.

Other countries have either left control of the pest to its natural enemies or endeavoured to reduce its incidence by the use of bait traps or sprays. These in their simplest form are sweet sugary solutions containing an insecticide such as lead arsenate, sodium fluosilicate, DDT or malathion, and a fly attractant such as protein hydrolysate may be included to obviate the necessity of obtaining complete coverage during blanket spraying. An example of a typical bait spray recently used successfully in Florida is 1 lb. protein hydrolysate, 1 qt. concentrated sugar solution and 2–3 lb. of 25% malathion wettable powder, mixed with one or more gallons of water and applied by aircraft or ground machines evenly over one acre at intervals of 10–14 days.

BIOLOGICAL CONTROL

For many years biological control of the citrus pests has received a great deal of attention by research workers at all levels. Valuable information has been accumulated; predators and parasites have been transported from one continent to another; insect breeding centres have been established, and in many areas large populations of beneficial insects have been released into citrus. Subsequent observations have been recorded in great detail and analysed, but the results obtained have seldom been of benefit to the grower.

In California, for instance, introduction of the parasite *Metaphycus luteclus* has been mainly responsible for the disappearance of damaging populations of the soft brown scale, yet as soon as parathion was used for killing other scale species a local outbreak of soft brown scale invariably occurred. This reaction arises because parathion at that strength destroys the parasite but is ineffective against the soft brown scale. We also have the classical case of the vedalia beetle exercising biological control over the cottony cushion scale; any citrus grower with incipient infestation of this pest is always particularly careful to avoid applying such chemicals as malathion, parathion or DDT, which would upset the predator status.

Future work may be expected to yield information on the parasite/host relationship which will be of immense value to the applied biologist when formulating new chemical control methods against citrus pest complexes of known composition. But not even the ardent enthusiast really believes that the biological approach will ever succeed on its own, and workers in this field look forward to the day when the chemist will produce substances that are specific to the pests and non-toxic to the parasites.

CHEMICALS USED IN CONTROL

HCN Fumigation

Over 60 years ago HCN tent fumigation was introduced as a successful means of controlling insect pests on citrus. Its insecticidal efficiency far outweighed its phytocidal limitations: leaf drop, tip burn of new flushes, necrotic patches on leaves, spotting and scabbing and even pitting of fruit could be a normal expectation if the weather and the tree condition were not just right for fumigation. The methods used were slow, laborious and hazardous to operators, yet HCN treatment of citrus continued until the early 1920s, when Californian red scale began to show signs of cyanide resistance. Once resistance to HCN was proved, growers turned to oil and quickly abandoned the cumbrous method of fumigation.

Mineral Oil

Oil acts on insects in a very different way from HCN, as it kills by slow suffocation, but it is also liable to damage the citrus leaf under most conditions. Its virtues are that it has no application hazards and, when used as a 1½–2% emulsion for the control of scale, it automatically eliminates any spider mites which may be present. Because oil acts by suffocation it must always be sprayed at a high gallonage to ensure that not only the mites and insects on the fruit and leaves but the scales on inner branches and trunk are completely covered. Experience has shown that to satisfy these conditions 1500–2500 gallons of spray wash per acre is required on mature trees.

In the early days the dangers of oil application were not fully appreciated, and it is only recently that sufficient evidence has been accumulated to indicate that the margin of safety is precariously small. A light leaf drop occurring 7–10 days after treatment is regarded as a normal consequence of oil spraying, and this will be exaggerated if insect damage is heavy, temperatures are high or soils are dry at the time of treatment. Excessive fruit and leaf drop must be expected if three weeks do not elapse between applications of sulphur and oil, or if the oil is applied too soon after blossom fall. Late season treatments cause delay in colouring, may remove bloom from the fruit, and probably reduce next year's yield.

Despite these practical limitations oil has been used in very large quantities and still will be used on citrus for many years to come, because it is cheap, easy to apply, and effective against both scales and spider mites.

Sulphur and Zineb

Normally sulphur and zineb are regarded in the crop protection world as fungicides, but for citrus they have an additional use, as they give good control of rust mites. Until the late 1950s sulphur was the only chemical used commercially against rust mite in the field. Its phytotoxic limitations are probably even greater than those of oil, for irrespective of the formulation there is always the danger of burning the fruit if cool temperatures do not continue for 7–10 days after application. Injury takes the form of "sulphur burn" on fruit directly exposed to the sun, and the damage is liable to increase in severity as the temperature approaches 100° F. Growers with rust mite problems cannot avoid taking risks, for effective control can only be obtained if a properly timed programme involving 3–6 routine applications of sulphur during the growing season is followed. Dusts at 25–60 lb./acre and wettable powders at spray strengths equivalent to 10 lb./100 gal. are less hazardous than 2–5% lime-sulphur sprays.

In searching for a more acceptable chemical than sulphur, workers in Florida during 1954–56 found that another fungicide, zineb, gave excellent control of rust mites when applied as a full cover spray at 1 lb./100 gal. Zineb is more persistent and considerably less phytotoxic than sulphur and, in consequence, is bound to gain popularity with growers and to be used on an increasingly large scale in the course of the next few years.

Hydrocarbons and Organic Phosphates

Unless their application to citrus foliage is essential, use of such persistent hydrocarbons as DDT, BHC, and dieldrin is discouraged because of the likelihood of their upsetting the predator status and creating new and more serious problems. Main uses for these chemicals are as insecticidal components in certain bait sprays and for spraying the trunks of citrus trees and adjacent ground to prevent damage from insects like the pinhole borer, ants and fiddler beetles.

Within a very few years of its introduction in late 1947 parathion proved itself to be effective, versatile and acceptable to the citrus industry. Its quick and spectacular success stimulated research to such an extent that many hundreds of phosphorus chemicals showing great variation in mammalian toxicity, pesticidal selectivity and rate of absorption or decomposition on and within plant tissues were tested, in an effort to obtain a related chemical combining even greater activity with reduced toxicity hazard to man. To date these efforts have been unrewarded, and parathion is still preferred because of its great biological efficiency, wide range of action and cheapness. It acts as a partial systemic and has the ability to penetrate and kill across a leaf, giving effective control of almost all the more important mite and scale species found on citrus. Unfortunately it is ineffective against rust mites and only has a short effective residual action of 4–10 days, which means for mite control that two properly timed applications are necessary. As an acaricide and scalicide, malathion is much less effective than parathion. Systox, on the other hand, which is a true systemic, is more effective on spider mites than parathion and is capable of giving from 6 to 13 weeks' protection against these pests; but it is ineffective against scale insects and rust mites, and like parathion needs special care during application.

Although large volumes of phosphorus chemicals will no doubt be applied to citrus in the next few years, research workers are fully aware of the significance of the presence of phosphorus-resistant spider mite areas in California and the use of very high parathion rates which are necessary to control Californian red scale in South Africa. The indications are that the organic phosphorus era on citrus may be short.

Application Equipment

The development of machines and devices for applying pesticides has been so rapid in the last 25 years that some citrus areas have moved from the old hand application methods to the ultra-modern air-assisted speed sprayers. Shortage of labour, higher costs of production and the introduction of more toxic chemicals must be regarded as main reasons for this change rather than desire on the part of the grower to depart from hand spraying, which even today will give the most secure biological result. Before considering the subject it is important to understand the application problems that are specific to citrus.

Firstly, citrus trees can vary in size from young plantings 2–3 ft. tall to mature trees 20–25 ft. high and 12–18 ft. in diameter at the base of the canopy. The outer canopy of citrus in bearing is always so dense that it is difficult to penetrate, yet the area near the trunk is "hollow" and devoid of foliage.

Secondly, because of their different habits, mites and scales require different treatments. When applying chemicals against spider mites and rust mites, which are active leaf-feeding pests with normal habitats in the outer canopy, the aim is merely to obtain adequate coverage of the foliage alone. This is usually achieved by applying 250–300 gal. of spray wash per acre, i.e. 3–6 gal./tree. For scale control, however, application is much more difficult because not only the leaves but also the fruit twigs, branches and main trunk must be completely covered. This necessitates applying 1000–2500 gal. per acre, i.e. 12–30 gal. per tree.

Hand Application and Boom Sprayers

Hand application of insecticides to citrus is still common in areas where costs are low, labour shortage is not acute, or the terrain is unsuited for automatic machines. The spray reservoir is usually a 400–600 gal. tank, tractor drawn or truck mounted, which is fitted with a constant pressure pump and from which 3 or 4 hoses are run off. As every part of the tree should be sprayed from every direction, at least one of the hoses is normally operated from a high adjustable platform (Figure 5) so that some of the spray can be directed downwards into the top of the tree while the remainder is poured on from ground level.

Boom sprayers were introduced about 1935, and the earliest models were simply upright tubes bearing a series of coarse nozzles through which spray was ejected under considerable pressure. Single-sided and double-sided adjustable upright booms soon gave way to the more streamlined approach of having the nozzles arranged in a semicircle. Excellent results on mites and fair control of scale have always been obtained with these machines provided the gallonage applied per acre was maintained at a high level. In an attempt to get greater penetration through the outer canopy and better scale control in the inside of the trees, the oscillating boom was evolved. This embodies mechanical devices which impart a slight movement to the boom or individual nozzles, thus giving the spray a vertical or circular swirling motion.

Boom sprayers are still extremely popular and may be either tractor-drawn or truck-mounted (Figures 4, 8). Improvements and modifications in progress may be instanced by the long arched double boom (Figure 7), which not only sprays the sides but into the tops of trees in two adjacent rows. To ensure effective cover a normal working speed of 1–1½ m.p.h. is recommended. Mobile nurse tanks keep these machines constantly supplied with a ready-mixed spray solution.

Atomizers, Dusters, Aerial Application

Two types of atomizing machines are being developed for use on citrus. Both employ air to carry small concentrated spray particles into the tree. A fan propeller or a turbine produces the blast of air, which passes over the liquid discharge orifices and causes the spray to be atomized. Such machines (Figure 6) are heavy and expensive, but can be operated by one man and, it would seem reasonable to suppose, will control rust and spider mites. Scale control will probably depend on whether the machine is capable of displacing the entire air under the leaf canopy and introducing the highly concentrated atomized spray.

It is well known by citrus growers that biological results with dusts are rarely as good as those obtained with sprays because of the natural tendency for operators to apply too little dust at too high a travelling speed. Both tractor-mounted and air-blast dusters are available, but interest in this type of equipment is diminishing each year.

Aircraft are in common use for blanket spraying of baits but have not yet become widely acceptable for applying chemicals against foliage pests. This is strange, for growers are well aware that the aerial application of certain systemic miticides can give excellent control of spider mite when two spray runs, each at 2–5 gal./per acre, are made at right angles to each other in the same grove. The method has so many advantages to offer that it is logical to expect its use to become more widespread within the next few years.

Conclusions

The citrus industry is extremely cautious in its approach to, and acceptance of, new chemicals. New chemicals will never be recommended until they have been fully tested and all side-effects are either known or anticipated. Since the early days of HCN only oil, sulphur, parathion and malathion have been universally accepted, and they are still widely used. Oil and sulphur have serious phytotoxic limitations when applied to citrus. Zineb has recently been accepted as a rust mite chemical and will slowly replace sulphur against this pest in many areas. Some specific miticides may receive local acceptance.

Detailed ecological studies of economic pests and intensified efforts into biological control methods have produced much valuable information and a better understanding of the mite/scale complexes that are present on much of the world's citrus. Mite resistance to organophosphates, Ovotran and Aramite is being investigated and closely watched.

Spectacular advances have been made in the field of application. Automatic machines have overcome the labour shortage problem and provided new methods of applying miticides. It is doubtful if the tendency to apply lower and lower volumes per acre will continue. The problem of ensuring complete coverage of the trunk and inner branches by automatic machines has not been solved. The use of aircraft is likely to extend in the near future.

The type of chemical required by the citrus industry may be defined as a non-phytotoxic, true systemic of very low mammalian toxicity, having a long residual action and effective against all types of scale and all species of mite. This specificaton is not impossible, and to judge from co-ordinated research work in progress it seems reasonable to expect that it may eventually be met.

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VIRUS PNEUMONIA OF PIGS

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Virus pneumonia is a common chronic respiratory disease of pigs, which causes considerable economic losses because affected fattening pigs have an inefficient food conversion ratio and slow growth rate. Attempts are being made in the field to establish and maintain herds free from the disease. In the laboratory, work is being aimed at identifying and culturing the causal agent in the hope of developing some specific methods of diagnosis.

It is well recognized in many countries that various chronic respiratory diseases of pigs are very common and have a detrimental effect on the growth rate and productivity of the animals. One of the more important of these infections is virus pneumonia or enzootic pneumonia.

In 1941 [8] the position in England regarding chronic respiratory diseases was assessed as follows: "Infectious pneumonia of pigs has been recognized by practitioners for many years—in severe cases there was a chronic phase which lasted several weeks. The pigs then became unthrifty and suffered from a chronic cough, but they eventually recovered." At this time practically no precise information about respiratory diseases of pigs in Britain was available, but in 1951 a chronic infectious pig pneumonia, which was common in the United Kingdom, was clearly differentiated from the acute disease swine influenza [15]. Although a chronic form of influenza was at this time presumed to be a common disease, it was not possible to isolate influenza virus from outbreaks of pig pneumonia in East Anglia and Northern Ireland, nor could antibodies against this virus be demonstrated in the sera of recovered animals. It was shown that bacteria-free filtrates of pneumonic lung were infective, and that compared with swine influenza the onset of the disease was slower, the course was more protracted, and the infective agent persisted longer in the lungs.

It appears that similar chronic pneumonias occur in many other countries. There are not yet any specific means of comparing these pneumonias, and although there are minor differences between the descriptions of these diseases they share many important features: all are non-bacterial pneumonias having an incubation period of up to several weeks and a protracted course with a detrimental effect on growth rate.

The object of this paper is to show the place of virus pneumonia among the other pig respiratory infections, to summarize the present knowledge on the disease, and to indicate those features which are of help in diagnosis.

THE CHRONIC RESPIRATORY DISEASES OF PIGS IN GENERAL

It is only within the last decade that it has been realized how prevalent respiratory diseases of pigs are in Britain. In the field, obvious acute clinical pneumonias are fairly frequent, but it is the relatively mild but chronic respiratory diseases that occur so very commonly. These chronic diseases are of two main types: (*a*) rhinitis—an inflammation of the nasal cavity—and (*b*) pneumonia. Although rhinitis is an important disease complex, its description is beyond the scope of this paper.

The prevalence of the relatively mild pneumonias can be appreciated from the fact that examinations of lungs of apparently healthy fat pigs sent into bacon factories have shown incidences of consolidated lesions between 42% and 55% [1, 3, 15, 20, 25]. There seems little doubt that even some of the lungs which appeared normal were from pigs that had suffered from pneumonia in earlier life and then fully recovered.

It was at first widely presumed that most of these consolidated areas in the lungs of bacon pigs were lesions of virus pneumonia (enzootic pneumonia). From general considerations one would not expect this to be so, since in other species, including man, it has been found that the chronic pneumonias are a very complex group of conditions. There are many different primary causal agents (e.g. viruses, pleuropneumonia-like organisms (P.P.L.O.), bacteria, fungi and parasites), and frequently secondary agents contribute to the severity of the disease and prolong its course. For example, in the chicken at least six diseases which are similar clinically and pathologically may be caused by five different viruses and one pathogenic P.P.L.O., various bacteria and non-pathogenic P.P.L.O. being important secondary agents [12]. It is also often very difficult in chronic respiratory diseases to distinguish between primary and secondary agents, particularly since predisposing factors (e.g. system of housing and management) contribute to the establishment and maintenance of these chronic pathological conditions.

In the case of the common chronic respiratory diseases of the pig very few of the primary aetiological agents have been identified, and the role of those that have been isolated is usually uncertain. For example, although influenza virus has been isolated from chronic pneumonias of the pig [8, 20] it is very doubtful whether this agent was the cause of the disease, since the influenza virus produces in pigs, as in other species, an acute, not a chronic disease. Similarly most of the organisms that have been isolated from the common chronic respiratory infections of pigs appear incapable of producing a similar chronic disease experimentally.

Although the pneumonias can be roughly divided into groups on a histological basis, there are not yet any published reports of the proportions of the different pneumonias in bacon pigs in this country. In the writer's experience pneumonia microscopically indistinguishable from virus (enzootic) pneumonia is seen more commonly in the bacon pig than any other type of pneumonia, but he has also seen many other types, including pneumonia associated with rhinitis, lungworm infections, swine fever and tuberculosis, and pneumonia due to inhalation of vegetable material. In addition, it is common to see healing pneumonic lesions remaining from several types of piglet pneumonia. Which particular type is seen most commonly must depend on the characters of the infective agent coupled with the opportunities provided for its spread and maintenance as well as on the ages of the pigs examined. It so happens that the system of management adopted during the fattening period in most commercial pig herds favours virus pneumonia perhaps more than any of the other respiratory infections.

In our experience, the pigs are infected with virus pneumonia in a very high proportion of the intensive fattening houses in Britain. Practically the only fattening houses free from the disease are those in herds from which the infection has been deliberately eradicated or avoided by purchasing only healthy stock. In a very few instances we have seen fattening houses that happen to be free from the disease, but in all cases they have been in self-contained herds which have been established from a small number of breeding stock that presumably were free from virus pneumonia. Because communal fattening houses are so numerous in this country, a large number of the nation's growing pigs are exposed to the disease.

DESCRIPTION OF VIRUS PNEUMONIA

Clinical Signs

Virus pneumonia, when uncomplicated, is clinically a relatively mild disease in which the principal sign is a chronic, harsh, non-productive cough. Apart from the cough there is often little clinical evidence of the pneumonia which is often only detected on post-mortem examination of the slaughtered pigs.

Coughing usually commences 7–30 days after exposure to infection, and the onset of the disease is gradual. Affected pigs may cough for weeks or months, but there is slow recovery. Some animals recover completely; others apparently recover but are still capable of transmitting the infection. Some infected pigs never develop the cough. Although affected animals are not obviously ill, they are unthrifty.

Some pigs do develop an obvious severe pneumonia and pleurisy. These complications are usually associated with multiplication of secondary bacteria which alone do not produce pneumonia. Deaths are rare, and even in acute cases the animals usually make an apparent recovery, although they do remain chronically affected. The disease is generally more severe, and there are more cases of acute pneumonia when pigs are crowded in a building with restricted air space or when the infection is newly introduced into a herd.

Epidemiology

The epidemiology of a disease is dependent on many factors closely related to the fundamental properties of the causal agent and the hosts that it infects. In the case of virus pneumonia where there are no specific means of diagnosis, the epidemiology, because of its rather characteristic features, becomes of great importance in diagnosis.

As far as is known, the agent causing virus pneumonia will not infect animals other than the pig; certainly there are no confirmed reports of transmission of the infection to laboratory animals. In the field there is no positive evidence to indicate that species other than the pig become infected, although this possibility cannot be excluded. The causal agent appears to survive only for a short time outside the pig, e.g. premises vacated only 10 minutes previously did infect 1 of 2 pigs exposed to risk [4], but premises vacated 24 hours previously did not infect pigs [32]. A longer survival of the causal agent is likely to occur occasionally in the field, since it may have been dried under special conditions of humidity and temperature.

Virus pneumonia has only been produced experimentally by spraying or inoculating suspensions of infective lung directly into the respiratory tract. Inoculation of infective lung suspensions by other routes (e.g. subcutaneously, intradermally, intravenously, intraperitoneally or intrapleurally) has not produced pneumonia [4, 32].

When a pig becomes infected the causal agent may persist in the respiratory tract for several months, sometimes for longer than a year [3, 13, 16, 18]. Many pigs which have developed pneumonia and clinical signs of infection make an apparent recovery but still harbour the infective agent.

The causal agent leaves infected pigs via the respiratory tract mainly in the minute droplets expelled during coughing and sneezing. The disease spreads almost entirely by the airborne route, and mechanical transfer or vectors are believed to be of little or no significance [4]. It is not highly infectious, and usually more than a slight exposure to risk is necessary to initiate infection. Nevertheless, in intensively managed herds where there is every opportunity for the spread of the infection, the morbidity is high.

Although no neutralizing antibodies have been demonstrated in the sera of convalescent pigs [4, 19, 22], recovered animals do not develop a clinical disease on experimental re-infection [22, 32]. Field evidence also indicates the development of some low-grade immunity, since, in infected herds, pigs do gradually recover. For example, breeding stock running out of doors rarely show obvious signs of the disease, and the carrier sows do not appear to re-infect sows that have recovered completely. In contrast, carrier sows do infect their litters. There is no evidence of age immunity, since all ages of pigs can readily be infected experimentally. Similarly, when a herd is exposed to infection for the first time, pigs of all ages become clinically affected, and often the adult stock develop a severe and extensive pneumonia.

Pathology

The main pathological lesion is a pneumonia of the anterior and inferior parts of the lung. Figure 1 is a photograph of a bacon pig's lung affected with virus pneumonia. There is nothing particularly characteristic about the naked eye appearance or distribution of the pneumonic lesions, since they closely resemble the lesions seen in several other types of pig pneumonia.

The typical microscopic changes in the pneumonic areas include a proliferation and desquamation of the alveolar cells, and mononuclear cell accumulations associated with the bronchioles and small blood vessels. As the disease slowly progresses the accumulations of mononuclear cells become more marked; during recovery they gradually become more discrete and disappear. Although these microscopic changes are constantly seen in virus pneumonia, they are not sufficiently distinct to be diagnostic. No specific histological features have yet been described.

Aetiology

The nature of the causal agent is still uncertain. It has been known since 1933 [17] that bacteria-free filtrates or suspensions of pneumonic lung are infective. A number of workers have found that filtrates that have passed through pores of diameter about 800 mμ are infective for pigs [4, 14, 26]. The author concludes from his own experiments that the diameter of the smallest infective particle is between 200 and 450 mμ [32]. Suspensions of pneumonic lung which have been treated with antibiotics are also infective [5]. Although establishment of infection can be prevented by the oxytetracycline group of antibiotics, established cases of pneumonia cannot be cured by the drugs at present available [5]. All these findings together suggest that the causal agent is either one of the larger viruses or some other organism of similar size, such as a rickettsia or a P.P.L.O. It should be just possible to resolve an organism of such a size under the ordinary light microscope.

An organism of the right size to be the causal agent has been found by the writer [32] in Giemsa-stained impression smears prepared from lungs of cases of virus pneumonia. This organism has been found in all his British experimental strains of virus pneumonia, in one Swedish experimental strain, and in cases of pneumonia in all the twenty herds in which he has studied the typical disease. It does not appear to be associated with other types of pig pneumonia. The organism, which occurs mainly extra-cellularly and is very pleomorphic, shows similarities in morphology, staining reactions and distribution to the P.P.L.O., but it has not yet been cultivated, so that its identity remains uncertain,

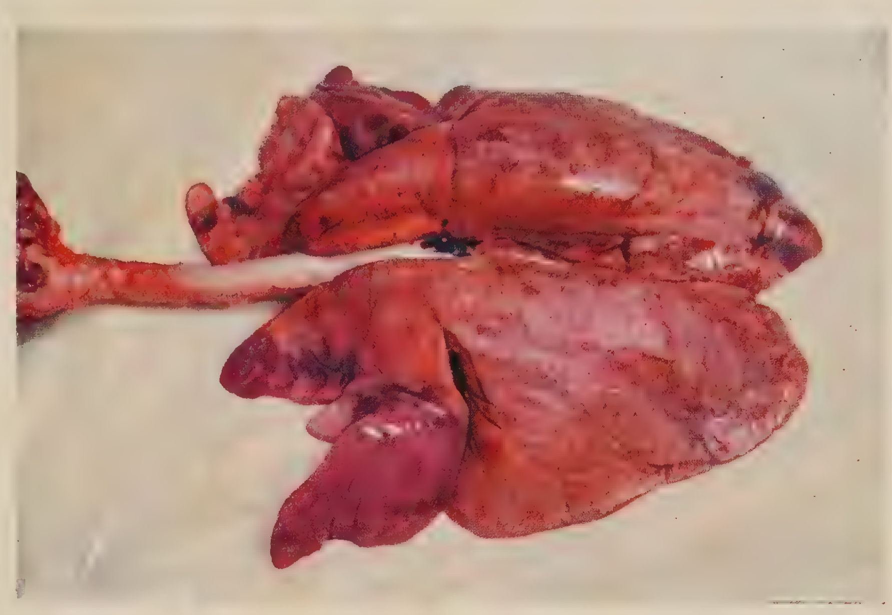

FIG. 1. The trachea and pair of lungs from a bacon pig affected with virus pneumonia. The most obvious pneumonic areas are the dark areas on the left apical and cardiac lobes (left foreground); there is nothing diagnostic about this appearance, since other types of pneumonia appear similar by naked eye examination. There are also some consolidated areas at the tip of the right diaphragmatic lobe (upper right); these lesions are associated with lungworm infection.

nor is it known whether it is the prime cause of virus pneumonia, though considerable circumstantial evidence does suggest that it may be involved [32].

Swedish workers [23, 30] have isolated, from cases of virus pneumonia, a similar organism which grows intracellularly in epithelial-cell tissue cultures. These workers are uncertain of the identity of this organism, but they [24] think that it may be a P.P.L.O. with an intracellular phase of multiplication. Suspensions of tissue cultures containing the Swedish organism produce a pneumonia in pigs [24], but this disease is not likely to be virus pneumonia, as it is not transmissible from pig to pig [21].

The position is considerably complicated by the fact that apparently non-pathogenic P.P.L.O. have been isolated from the respiratory tract of pigs infected not only with virus pneumonia but with other respiratory diseases and from some apparently normal animals [9–11, 27, 32].

The role played by the different organisms described (i.e. (*a*) the virus thought by some writers to be present, (*b*) the pleomorphic organism described by the writer, (*c*) the organism isolated in tissue culture by some Swedish workers, and (*d*) the cultivated P.P.L.O) in the causation of virus pneumonia is likely to be under discussion for some time.

THE EFFECT OF VIRUS PNEUMONIA

That virus pneumonia has a detrimental effect on the growth rate of pigs has been demonstrated in a series of experiments in Britain [7] comparing the performance of pigs experimentally infected with virus pneumonia with that of their uninfected litter-mates. Using an apparently typical strain of the disease and measuring the effect of the disease between weaning and bacon weight, the growth rate of the infected pigs was found to be depressed by 16% and their food conversion efficiency by 22%. The results of these five experiments, which involved 59 control and 61 infected pigs, are summarized in Figure 2.

In these experiments the infected pigs were no more severely affected clinically than naturally infected animals. In fact in nearly all the infected pigs, apart from the chronic cough and some roughness of the skin, no abnormalities were detected on casual observation.

The effect of virus pneumonia in the field varies enormously from herd to herd, according to such factors as (*a*) the system of management, which affects not only the number of pigs exposed to the infection but the clinical severity of the individual cases, and (*b*) the presence of secondary agents, some of which increase the clinical severity even to the point of producing severe bacterial pneumonias.

There does seem to be little doubt, however, that if the majority of pigs in a group are infected with clinical virus pneumonia the effect on productivity is at least as severe as in the above experiments. It is in the large communal fattening house, particularly when badly insulated and badly ventilated, that the maximum effect of the disease is

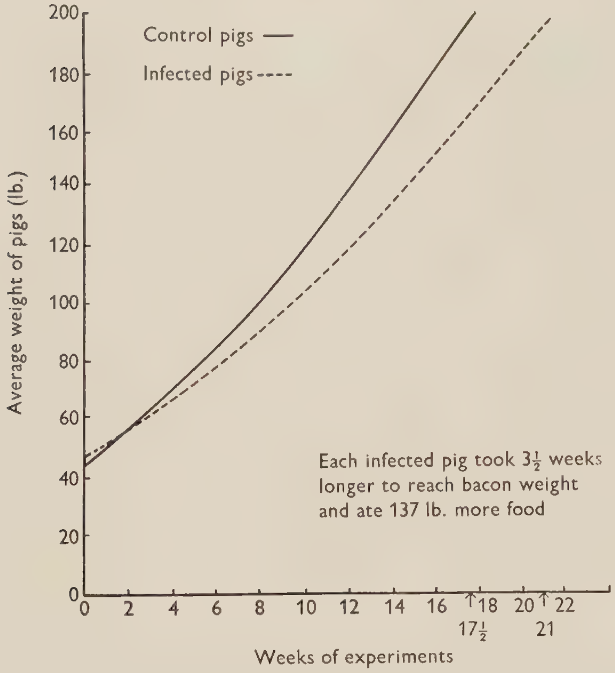

FIG. 2. Mean growth rate of 59 control pigs and 61 pigs infected with virus pneumonia in five experiments conducted at Cambridge and Compton. (Modified from Betts *et al.* [6].)

seen, and in these circumstances its eradication will strikingly improve the performance of the pigs.

The disease is least harmful in self-contained herds where the pigs are kept in small groups isolated from each other. In some herds it may be present without causing obvious unthriftiness or showing appreciable clinical evidence of infection—indeed, the only clear indication of its existence may be that the breeding stock are capable of initiating infection in other herds known to be free from the disease.

Because of the widespread occurrence of virus pneumonia and its ability to reduce the performance of pigs even when they are not obviously affected, the disease is of considerable economic importance in this country, though other respiratory diseases can also cause severe losses.

CONTROL OF VIRUS PNEUMONIA

Since virus pneumonia seldom causes death and the losses are mostly of a hidden nature, some infected herds even continuing to make a profit, its control has not been looked upon as a matter of urgency. Moreover there is at present no easy way of controlling the disease: the drugs that have been tested do not cure established cases; there seems to be little hope of developing a satisfactory vaccine; and there is no objective means of diagnosis. Because of the high proportion of sub-clinical cases and the extreme difficulty of detecting them it is not possible to eradicate the disease from a herd merely by eliminating affected stock. These features, together with the lack of precise knowledge on the disease, make an official control scheme largely impracticable unless extensive laboratory facilities can be made available.

Nevertheless it is possible, though difficult, to eradicate virus pneumonia from infected herds and to maintain herds free from the disease by suitable hygienic measures [6].

It was shown in 1934 [28] that a knowledge of the epidemiology of piglet pneumonia* could be used to prevent the spread of infection, and in 1937 the German workers [29] wrote: "As there is no effective drug or specific immunizing agent against piglet pneumonia, and as the carrier is such a prolific source of dissemination, the chain of infection can best be broken by maintaining piglets in the smallest possible units"; and after describing details of the method to be adopted they say: "These methods have eradicated the disease." It seemed probable, therefore, that virus pneumonia could be controlled in a similar way.

In 1955 the first reports of attempts to control virus pneumonia in Britain were published [2, 6, 25, 31]. Healthy herds may be obtained (*a*) by total replacement of the herd with healthy stock, (*b*) by purchasing healthy foster mothers to rear newly born piglets (i.e. the farmer's own blood lines can be preserved, (*c*) by artificially rearing piglets or (*d*) by determining a healthy nucleus within the infected herd. These methods must be combined with suitable measures to prevent the healthy stock becoming infected from other pigs.

It is possible to obtain a nucleus of healthy pigs from an infected herd because a proportion of breeding sows do recover completely from virus pneumonia. The method consists of the following steps:

(*a*) Selected sows are farrowed in a sufficient degree of isolation to prevent the airborne transmission of infection from one pen to another. In the open air a distance of several yards between pens is adequate. In enclosed buildings each isolation pen must be completely sealed internally, and there must be no possibility of infected air gaining entrance through the doors or windows.

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* The German workers used the name *Ferkelgrippe*, i.e. "piglet influenza," but there is, in fact, little evidence that the influenza virus was implicated. The disease appears to resemble virus pneumonia in many respects.

(*b*) The sow is removed from the pen when the litter is 8 weeks old, but the litter is retained in isolation for a further 4 weeks. During these 12 weeks the litter is continually observed for any clinical signs of respiratory infection.

(*c*) Two piglets are sacrificed from each apparently healthy litter to check for pathological evidence of respiratory infection.

(*d*) Several litters judged to be healthy are grouped, but the group is retained in isolation and kept under continual observation.

(*e*) When the pigs reach marketable weight the gilts, not retained for breeding, and the hog pigs are slaughtered and examined post-mortem for evidence of respiratory infection.

(*f*) The remaining gilts and boar pigs in the group, thus judged to be free from virus pneumonia, are used to establish a new herd. At no time is any possible contact allowed between the healthy nucleus and the old herd, which is disposed of as soon as possible. Even the sows that produced the healthy litters must be discarded.

Because of the economic advantages in owning a herd free from virus pneumonia, particularly when breeding stock is sold, it has become fashionable to claim that herds are "free from virus pneumonia." Many of these claims have been made on very little evidence—in fact, the pigs in some of these herds have been kept under a system of management that would make the disease inapparent and consequently very difficult to detect even if it were present. Farmers who have little experience of the disease often think that it is absent just because it is not obvious. Thus breeding stock, believed to be healthy by honest but misguided people, may be able to infect a healthy herd and do enormous damage.

A group of progressive farmers, stimulated by this danger and having a genuine desire to form a nucleus of reliable herds free from virus pneumonia, have recently formed an Association for the Advancement of Virus Pneumonia Free Pigs. With some veterinary advice this Association drew up a set of provisional standards to be adopted in those herds claiming freedom from virus pneumonia. It is not yet known whether these standards are capable of detecting all the herds that are infected.

The writer pointed out to the Association that the most reliable check that a herd was free from virus pneumonia could be provided if a system of management was adopted which would make the disease obvious if it were present. In the large fattening house which contains infected pigs, and which is never emptied, virus pneumonia is usually clinically obvious; when the pigs are slaughtered the pneumonic lesions are obvious and have the typical microscopic appearance. Thus the disease is fairly easy to detect in young pigs in this type of fattening house. In contrast, it is least obvious in the adult pig that has been kept on free range for a long period; in self-contained herds such adult stock rarely show any indication of infection except that a proportion of them remain capable of transmitting the disease.

In deciding which herds really are free from virus pneumonia the method of checking must be capable of detecting the disease if it is present in *any* of the stock. The method that has been adopted makes the assumption that a sow, if a carrier, intermittent or otherwise, will on some occasion infect at least one of her litters. Thus if some piglets from every litter farrowed on the farm are put into a large communal fattening house which is never emptied of pigs, the disease has every opportunity to spread. Having ensured that the disease will become obvious in the fattening house if any of the pigs are infected, examinations of the lungs of the slaughtered baconers will indicate the presence or absence of virus pneumonia in the herd. The failure under these conditions to detect lesions microscopically typical of virus pneumonia is believed to be the most reliable evidence that the herd is free from the disease.

Unfortunately there is a delay of at least six months before the lungs of pigs infected from their carrier dams can be examined. Moreover some carrier sows do not appear to infect all their litters. For these two main reasons the writer suggested to the Association that it would be advisable, even in a self-contained herd with a fattening house, to examine the lungs of bacon pigs for a period of at least 18 months before it would be safe to consider the herd free from virus pneumonia.

Much less is known about the behaviour of virus pneumonia in less intensively managed herds. In herds without a fattening house the detection of virus pneumonia is more difficult and its differentiation from other respiratory disease is more complicated, making it much harder to say when virus pneumonia is absent.

SUMMARY AND CONCLUSIONS

Although virus pneumonia seems to be well known to nearly all pig keepers and would seem to be quite a well defined condition in the field, the most striking thing about it scientifically is that because the causal agent has not yet been isolated or identified with certainty there is no general agreement about what should be included within the name "virus pneumonia."

The term virus pneumonia (enzootic pneumonia) is being used by the writer to describe a disease with the following main features: it is a chronic contagious disease of the respiratory tract of pigs, in which there are lobular consolidations of the anterior and inferior portions of the lung and in which microscopically there is proliferation of the alveolar cells, and mononuclear cell accumulations associated with the bronchioles and small blood vessels. Infection occurs only by inhalation, and the minimum incubation period, as judged by the development of pneumonia detectable by naked eye examination of the lung, is 5 days. The disease similarly affects pigs of all ages and produces mainly mild clinical signs. When the disease is introduced into a previously uninfected herd an acute clinical disease may occur, but the disease is usually chronic and enzootic. It is caused by an agent which passes pores of average diameter 0·8 μ and which is present in the lungs at all stages of the disease. It has not yet definitely been cultivated. Infection of pigs has only been prevented to date by the tetracycline antibiotics. A low-grade immunity follows actual infection, but no neutralizing antibodies have yet been demonstrated in the sera of recovered pigs.

The gaps in our knowledge on the aetiology of virus pneumonia are important, since most specific methods of diagnosis, as well as many of the methods for studying a disease, are dependent on isolation of a causal agent. Effective national control of virus pneumonia would be highly desirable economically, and this would obviously be simplified by some specific method of diagnosis. Thus, apart from scientific interest, further advances in the understanding of the aetiology would be of the maximum value.

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BOOK REVIEWS

Efficient Use of Fertilizers. Edited by V. Ignatieff and H. J. Page. Revised and enlarged edition. F.A.O. Agricultural Studies No. 43. Pp. xxii + 356, with 43 illustrations. F.A.O., Rome. 1958. 22s. 6d. net.

World population increase and higher living standards are outstripping world food supplies. Higher crop yields per acre are essential if the leeway is to be made up and if maximum use is to be made of a diminishing area of cultivable land—diminishing because of the advance of industrialization as well as population increase. This book points a way to higher production per acre by adequate fertilization and is a major contribution towards bridging the gap in food supplies.

The eight chapters of the 1949 edition have been revised and enlarged and two new chapters added. The number of pages has thus been almost doubled. One new chapter deals with the economic aspects of fertilizer use—a controlling factor in underdeveloped countries where the peasant farmer has little available capital. Chapter 9, which is concerned with the soil and nutrient requirements of 31 major world crops, is of value especially to the tropical agriculturist. Much of the information, which is adequately documented, is presented in book form for the first time. In this chapter it is refreshing to find a brief account of the use of fertilizers on the grass crop.

Arguments for continuous arable cropping as against alternate husbandry with periods under a grass-legume ley are well presented, and the authors conclude that the decision rests with the relative cash returns of the rotation sequences. If the ley does not give the farmer at least the same cash return as his arable crop he is unlikely to consider the improvement in the fertility and crumb structure of the soil which will result from a period under ley.

Chapter 7 on cropping systems contains a sympathetic evaluation of "shifting cultivation" which is so often condemned without a hearing. In the same chapter the authors discuss green manuring, cover crops and mulches in some detail. But the deleterious effect of grass mulch on coffee in East Africa, where magnesium deficiency has been attributed to the antagonising effect of excess potassium in the grass mulch, has escaped notice. Nutrient imbalance does, however, receive its fair share of attention in Chapter 2.

The book is well indexed and well documented. It can be recommended unreservedly to all students of crop production wherever they may be; the information it gives about tropical soils and crops is particularly valuable. R. J. MCILROY

Agriculture and Ecology in Africa: A study of Actual and Potential Development South of the Sahara. John Phillips. Pp. 412, with map. Faber and Faber, London. 1959 63s. net.

Few agriculturists have had as wide an experience of Africa as Professor Phillips, and into this book he has put not only his resultant knowledge but his reflections on agricultural development.

The volume is divided into five "books." The first introduces the problems of agriculture and ecology which the author intends to discuss. The second and third (supported by an ecological map) outline at some length the ecology respectively of the forest and savanna regions, and the agricultural challenge which results in each. These two portions comprise the greater part of the work. Interlarded as they are with copious references to the literature, from which little of importance in any language has been missed, they make somewhat heavy reading for the student who has not the author's wide personal knowledge of these plant communities. This section is open to the criticism that, dealing with such a vast area, the information given about any one region is inevitably scrappy and will tell the local resident little that he does not know already, while only the keenest reader will persevere with regions not his own.

The fourth book deals with economic, health and planning problems related to African agricultural development. What is said is sound, but within this space the author can hardly do full justice to such topics as land tenure, the co-operative movement, or the possibilities of local processing of crops; some others, such as the provision of credit, and mechanisation, are not discussed. It may be felt moreover that Lord Hailey's revised *African Survey* has recently covered the same ground and in fuller detail.

Book Five contains "General Conclusions and Suggestions." Long years of experience are speaking here, under the author's general theme that "failure to study and understand Nature inevitably ends in disaster." Few will quarrel with the approach; but tropical agriculturists are moving towards the view that, while ecology undoubtedly provides a first broad guide to agricultural development, other aspects of science, such as plant physiology, must be increasingly brought in to determine the finer details. This point could have been brought out in Book Four, where the Gezira and groundnut schemes are compared with the projected Volta development, had the history of the first two schemes been treated in rather more detail.

The author's style is not light, and he has a maddening trick of inverting the natural order of subject and verb in too frequent sentences. This somewhat detracts from the attention which is due to so wide an experience. What class of reader will the book most benefit? To agricultural scientists working in Africa its message is already known; it could be of great value to those who are either not agriculturists or not Africanists. Such readers could with advantage include Ministers of newly formed African governments, and Americans who bring their alien expertise to the continent. What agricultural students in African colleges still desperately need is textbooks of ecology with a local background which will teach them the outline of a subject whose relevance to agricultural planning Professor Phillips's book so rightly expounds. G. B. MASEFIELD

The application of Genetics to Cotton Improvement. Sir Joseph Hutchinson. Pp. viii + 87. Cambridge University Press, London. 1959. 15s. net.

It is now almost 13 years since *The Evolution of Gossypium* by Hutchinson, Silow and Stephens was published, and during that period our knowledge of the wild species of *Gossypium* and of genetics in relation to cotton improvement has increased amazingly.

The present book, based on a series of lectures delivered in 1954, deals in the first 42 pages with the relatives of the cottons and with the origin and spread of both the Old and the New World cottons. This subject was covered in much greater detail in the earlier book, but the present account weaves the discoveries of the last dozen years into the general pattern of the evolution of this genus—so much of relic status as regards its wild species, yet so dynamic in its evolution as a commercial crop. In the earlier account the evolution of the A-genome diploid cottons was assumed to have taken place under domestication, probably in the neighbourhood of Mohenjo-Daro, from a local wild species probably of the B genome. Hutchinson now considers *G. herbaceum* race *africanum* (the truly wild cotton of southern Africa) to be "the modern representative of the wild ancestor of all diploid cottons," the first domestication taking place in southern Arabia. This whole account of the evolution of the diploids, as deduced from an imaginative use of cytogenetic data, archaeology, history, and the lie of the old trade routes, makes fascinating reading.

Hutchinson's discussion of the origin and spread of the New World cottons now brings in the evidence from the excavation of Huaca Prieta in Peru, where cotton lint and seed, considered to be *G. barbadense*, were recovered from layers estimated to be *c.* 4400 years old. In both books it is argued that man must have crossed the Pacific taking with him seeds of diploid Asiatic cotton, and that in this way the A and D genomes met to form the New World allotetraploids. Now that the African race of *G. herbaceum* is considered to be the most ancient of the A group, there would seem to be cogent arguments in favour of an *Atlantic* crossing. Hutchinson considers such a crossing most improbable, but if *G. barbadense* was in existence in Peru 4400 years ago, the alternative of a crossing of the Pacific, probably well over 5000 years ago, seems, from the distance involved, less likely.

The remaining chapters deal more directly with the application of genetics to cotton improvement. Hutchinson has achieved a most readable and interesting account, but to attempt in less than 40 pages to give anything approaching adequate coverage to such a vast subject is an impossible task. Considerable omissions were inevitable in such a brief account, but it seems a pity that Harland's mass pedigree system, used with such success in the improvement of Tanguis cotton, is not mentioned, nor the adaptation of this system used in the Sudan—a technique that, combined with gene transference work, gave a range of blackarm-resistant *hirsutum* and *barbadense* varieties now grown there on over 700,000 acres.

This book would have been greatly improved by the inclusion of a few maps in the text, to make it easier to follow the arguments on the origin, domestication and spread of cotton. R. L. KNIGHT

Tree Fruit Production. J. S. Shoemaker and B. J. E. Teskey. Pp. vi + 456, with line and half-tone illustrations. John Wiley & Sons Inc., New York. Distributed in the U.K. by Chapman and Hall, London. 1959. 56s. net.

This book deals with tree fruit production both from the practical and scientific points of view. It refers specifically to fruit culture in Canada and the United States of America, but can be read with interest and profit by students and growers in other parts of the world, provided that the differences in climate, cultural methods and varieties are borne in mind. North America has a shorter spring, a hotter summer and, in the north, a much colder winter than Britain; but the fundamental principles of fruit growing are the same the world over.

A chapter is devoted to each important fruit in turn, usually including a brief historical survey, a note on the economic importance of the particular fruit, and sections on propagation, varieties, planting, nutrition, soil management, pruning, harvesting, storage and marketing. Apples, pears, peaches, cherries and plums each have a chapter, and there is a special chapter on dwarf apples and pears, including details of trees on the vegetatively propagated rootstocks of moderate vigour commonly used in Europe. Although seedling rootstocks are at present used for nearly all fruit trees in the U.S.A., interest in clonal rootstocks that produce trees of a more manageable size is greatly increasing. Another chapter deals briefly with apricots, quinces and nectarines, and a final chapter with citrus fruits.

The major pests and diseases are described, and control measures are discussed in general terms—a sensible feature in these days of rapid introduction of new spray materials.

The authors write with great assurance, and in general their advice is good and up to date. Their views on pollination, pruning and fruit thinning may be of particular interest to British growers. The sections on viruses and on irrigation are weak, and one would have liked to see more on interstocks and on bulk harvesting. Some 800 references to research papers are included, but only 15 of these were published outside North America. Hence the book is not a good guide to world research. Nevertheless it is a valuable work that should be available in every horticultural department; and it will be useful to students and scientifically minded growers, alongside their set of Bulletins of the Ministry of Agriculture that at present form the most concise and practical summary of scientific fruit growing in Britain.

W. S. ROGERS

British Parasitic Fungi. W. C. Moore. Pp. xvi + 430. Cambridge University Press, London. 1959. 45s. net.

This is a book for plant pathologists everywhere. It is also a compilation of the greatest interest of the phytopathogenic fungi which attack plants in Britain and as such is a mine of information for the mycologist. It is, in short, a history of plant pathology in Britain condensed into just over four hundred crown octavo pages of bibliography and fact: few worth-while records can have been omitted. Mr. Moore is, of course, in a unique position to write such a book and has made excellent use of the opportunity. Abbreviation is the keynote, but a careful choice of type, the use of standardized citations, and the employment of asterisks to denote host plants named in the text facilitate reference to brief notes on the etiology and control of the diseases, these annotations being fully supported by selected literature references. Consistency has been maintained throughout. Part I comprises an unencumbered list of parasitic fungi arranged under the Latin names of host plants cross-indexed with their common names, so that it is possible at a glance to check disease records for any plant. Part II consists of an annotated list of parasites and their diseases arranged alphabetically. Not all mycologists or agriculturists will agree with some of the nomenclature used, although conidial states are referred to the perfect forms where known. For instance, Snyder and Hansen are followed in the treatment of *Fusarium*, *Ophiobolus* is preferred to *Cochliobolus* as the perithecial state of *Helminthosporium sativum*, and *Puccinia recondita* is not recognized: "mangold" is preferred to "mangel." All these, however, are controversial.

The book affords an insight to the trends of phytopathological research in Britain during the past fifty years, and provides much food for thought. A prodigious amount of information on *Phytophthora infestans* on potato is admirably condensed into six pages and that on *Corticium solani* on sixty-two hosts into five, while *Venturia inaequalis* on apple occupies three and a half. Two of the most destructive cosmopolitan parasites, namely *Ophiobolus graminis* and *Puccinia graminis*, however, are contained on less than two and on one page respectively. An indication of the value of the modern mushroom industry is given by the inclusion of thirteen fungi as parasites and twenty-one as weeds of beds. Despite the overall abbreviation there is no lack of interesting or important detail, as instanced by the single record of the killing of a tree, *Aesculus pavia*, at Kew in 1917 by *Botrytis cinerea*: neither are the recent advances in the young science of seed pathology neglected.

J. C. F. HOPKINS

ABSTRACTS

CROP PRODUCTION

Some effects of acidification of alkaline and calcareous soils. II. Effect on composition of soil solution under field conditions. S. K. Tobia and A. G. Pollard, *J. Sci. Fd Agric.*, 1959, **10**, 529–32.

Plots of a soil previously treated with different proportions of ground limestone were acidified five months later by additions of aluminium sulphate, ferrous sulphate, or sulphuric acid. Aluminium sulphate had by far the most extensive and persistent effect on the composition of the soil solutions. The amount of phosphate in soil solution was diminished by ferrous sulphate and sulphuric acid, and by an amount of aluminium sulphate that lowered the *p*H to 6·0; but larger applications of aluminium sulphate, which brought the *p*H below 4·6, increased the phosphate concentration. Aluminium sulphate reduced the calcium and markedly increased the magnesium; ferrous sulphate increased the magnesium and had little effect on the calcium; sulphuric acid increased the calcium and had no effect on the magnesium. Aluminium sulphate brought considerable amounts of manganese but much less iron into solution; ferrous sulphate had little effect on the manganese or aluminium levels; sulphuric acid had no effect on aluminium, manganese or iron levels. S.F.A.

Action of synthetic soil-conditioners in waterlogged soils. S. K. Warrier and A. G. Pollard, *J. Sci. Fd Agric.*, 1959, **10**, 565–8.

Soil alone or mixed with peat was shaken overnight with HPAN (hydrolysed polyacrylonitrile) or "Merloam" (a calcium compound of modified vinyl acetate-maleic acid polymer), and half of each sample was covered with an inch of water in a beaker and stored for a month. Both soil conditioners caused marked aggregation, but the HPAN treatment tended to produce aggregates predominantly >1 mm., whereas with "Merloam" under normal field moisture the aggregates were more uniformly distributed over the size ranges, and after waterlogging aggregates were predominantly in the 0·25–1·0 mm. range. HPAN under normal conditions increased the pore space and water uptake, but waterlogging tended to diminish these effects; "Merloam" had very little effect on pore space or water uptake before or after waterlogging. Time of penetration of water into soil columns was markedly reduced by the soil conditioners, especially by 0·1% of "Merloam." S.F.A.

Effect of rate of application of superphosphate on growth and yield of potatoes. K. Simpson, R. D. Verma and J. Dainty, *J. Sci. Fd Agric.*, 1959, **10**, 588–96.

On two soils in east Scotland, containing 25–50 p.p.m. available P_2O_5, height and weight of potato shoots were increased by dressings up to 2 cwt P_2O_5/acre, but yields of root dry matter after 8, 12 and 16 weeks and of tuber dry matter at harvest were not further increased by dressings above 0·66 cwt P_2O_5/acre. On three soils with 220–600 p.p.m. available P_2O_5, superphosphate had little effect on shoot yield, but dressings above about 0·5 cwt P_2O_5/acre delayed tuber development and depressed the final yield of tuber dry matter. There was a positive correlation between phosphate uptake and yield of tuber dry matter on the low-P soils and a negative one on the high-P soils; highest tuber dry matter yields were associated with a phosphate uptake at the 12-week stage of 30–35 lb. P_2O_5/acre, and uptakes above 40 lb. P_2O_5/acre appeared to be toxic. The proportion of ware to seed was much greater in 1955 (dry and sunny) than in 1954 (cold and wet); on the high-P soils superphosphate had no effect, but on the low-P soils the proportion of seed was increased by superphosphate. S.F.A.

The effect of granule size on the efficiency of granulated superphosphate used as a pasture top-dressing. F. B. Muller, *N.Z. J. agric. Res.*, 1959, **2**, 234–41.

The experimental pasture consisting mainly of ryegrass, white clover and paspalum was some thirty years old on a well drained granular loam of *p*H 5·8 which had not been top-dressed for at least ten years prior to the trial. During the four-year test period it received the equivalent of 242 lb./acre P_2O_5 applied at $1\frac{1}{2}$ yearly intervals as either ordinary superphosphate or a commercial granulated double superphosphate or granulated super as coarse granules ($\frac{1}{8}$–$\frac{3}{16}$ in.), medium granules ($\frac{1}{16}$–$\frac{1}{8}$ in.) or fine granules ($\frac{1}{32}$–$\frac{1}{16}$ in.). The dry matter yields are tabulated for the individual years and also the total yields over the whole trial period. Highest yields were obtained by using the medium or finely granulated material, the medium sized granules gave a 4% increase over the ordinary super and a 6% increase over the coarsely granulated superphosphate. During the fourth year the fine granules gave significantly higher yields than the coarse ones. Under dry conditions it appears that powdered super will give quicker responses, while under wet conditions it is the granular product. It is suggested that a granular material with at least 50% of the granules ranging from $\frac{1}{16}$ to $\frac{1}{8}$ in. would be at least as effective as ordinary super as a topdressing for pasture under normal New Zealand conditions. E.M.A.

Field experiments on phosphate fertilizers. A joint investigation. G. W. Cooke and F. V. Widdowson, *J. agric. Sci.*, 1959, **53**, 46–63.

In about 90 field experiments dicalcium phosphate dihydrate powder gave approximately the same yields of potatoes, grass, kale and barley as superphosphate; for swedes it was inferior in north-east England and south-east Scotland but equal to superphosphate in west England and Wales. A lightly ammoniated superphosphate and a more heavily ammoniated granular NPK mixture based on triple superphosphate were as effective as superphosphate on barley and potatoes but only two-thirds as efficient for swedes on acid soils. Nitrophosphate was consistently inferior to superphosphate for barley, potatoes and swedes. Gafsa rock phosphate on acid soils gave yields of swedes and kale similar to those given by two-thirds as much P applied as superphosphate; for grass on acid soils it was ineffective the first year but in the second year was as effective as superphosphate, whereas on neutral soils it had neither immediate nor residual effect. No difference was observed between coarse-ground and fine-ground Gafsa phosphate. S.F.A.

Some aspects of the potassic manuring of pastures. T. Walsh, J. Kilroy and P. M. McDonnell, *J. Dep. Agric. Ireland*, 1957–58, **54**, 44–62.

Field trials in recent years on manuring of grass for hay and dried grass showed strong positive interactions between nitrogen and potassium. The optimum dressing for hay was 2 cwt sulphate of ammonia and $1\frac{1}{2}$ cwt muriate of potash (50%) per acre; for dried grass the recommendation is a total application of 4–5 cwt/acre of muriate, 2 cwt in spring and 1 cwt after each cut. A nation-wide series of field trials on grazed pastures (assessed visually) showed a definite response to potash in 44% of the trials and a doubtful response in a further 31%; the response tended to be greater and more rapid on new leys than on permanent pasture. Lack of response on soils of low potassium values could be attributed to absence of clover, extreme deficiency of some other nutrient, or rapid fixation of potassium in the surface soil. While the main response to potassium was increased growth of clover, pot tests with cocksfoot showed that grass may respond directly to potassium. Although there was a tendency for grass tetany to increase with pasture improvement its occurrence could not be correlated with the potassium content of the herbage.

S.F.A.

Fertilizing of young oil palms in the Cameroons. H. N. Hasselo, *Plant and Soil*, 1959, **11**, 113–130.

The effect of all combinations of N, P, K and Mg applied twice a year to oil palm seedlings, planted out at 9 months, were assessed in a field trial. Over the first 18 months leaf length responded to N, K, NPK, N+Mg and NPK+Mg treatments, whereas with Mg alone growth was significantly less than with no fertilizer. Flowering was first observed two years after planting out; at this stage absence of Mg adversely affected leaf growth and delayed flowering. About the time of flowering there was a severe outbreak of crown disease which was more severe the more unbalanced the treatment, being particularly severe in the absence of Mg and in the presence of K alone. S.F.A.

Seed soaking as a method of supplying the molybdenum requirements of lettuce and tomatoes. G. L. Wison and L. F. Notley, *Aust. J. agric. Res.*, 1959, **10**, 621–7.

Lettuce (var. Imperial 847) and tomato (var. Grosse Lisse) seeds were soaked in sodium molybdate solutions and then grown in molybdenum-deficient nutrient media and compared with untreated seed grown in both complete and Mo-deficient solutions. With lettuce seed soaked for periods of 2 and 8 hours in solutions of 100, 500, and 2500 p.p.m. sodium molybdate and washed five times after soaking, deficiency symptoms appeared in all but those soaked for 8 hours in the most concentrated solution; the plants from these seeds were not significantly smaller than the Mo-supplied controls. Germination tests showed that soaking in concentrations of up to 50,000 p.p.m. sodium molybdate for 8 hours had no harmful effect. After three weeks' growth plants from the 5000, 10,000, 20,000 and 50,000 p.p.m. treatments for 8 hours were compared with the Mo-supplied controls. The only significant difference was a marked reduction in growth with the 50,000 p.p.m. treated lettuce. Tomatoes soaked at 10,000 and 50,000 p.p.m. gave rise to plants equal in growth to the controls after 77 days. Leaching losses of molybdenum occurred with well-washed seeds and the implications of such losses in the soil are discussed. It is suggested that unless there is much leaching or fixation by the soil gradient of Mo concentration between the soil and seed would soon become small and reduce the loss. E.M.A.

Acute zinc deficiency observed in cacao on certain soil types in Netherlands New Guinea. H. Schroo, *Netherlands J. agric. Sci.*, 1959, **7**, 309–16.

After a brief review of the causes of zinc deficiency in soil the author describes the visual symptoms in cacao and mentions reports of zinc deficiency in this crop from Trinidad, Ghana and Ecuador. Acute symptoms of zinc deficiency in Netherlands New Guinea, where cacao cultivation has only recently been practised, was observed on two soil types. On the first soil, a silty loam that was very old, acid, highly leached, infertile and low in available calcium, magnesium and phosphate, zinc deficiency occurred in two-year-old trees after a season of drought, but the following year after heavy rains the new flush looked healthy with only mild deficiency symptoms in some trees. On the second soil, a silty loam on alluvial deposits derived from mica schists and serpentine laterites, slightly alkaline due to the presence of magnesium carbonate, low in available potash but high in available phosphate, the value of zinc sprays was tested. Four-year-old cacao trees were sprayed every ten days from 10th August 1958 to 10th March 1959 at the rate of 2½ g. $ZnSO_4$ per tree. The sprayed trees improved considerably with 33 p.p.m. Zn in the healthy leaves, while the deficient trees had on average 20 p.p.m.

E.M.A.

On spacing of beets. C. T. de Wit, *Jb. Inst. biol. Scheik. Onderz. Wageningen*, 1959, 129–34. (With English summary.)

Results of continental experiments with fodder and sugar beets are represented graphically to show the relationship between crop yields and space available per plant. The straight-line relationship $O_x = O_0\{A/(A+x)\}$ (where O_x represents the yield and x the space available per plant) only holds over a limited range for x, the lower limit giving the optimal maximum plant population. For sugar beets on highly productive soils the maximum plant population appears to be of the order 900/acre (approx. 36,500/acre), but less on less fertile soils, owing perhaps to limited nutrient uptake, the number is considerably less. For fodder beets the optimum maximum plant density had not been reached in the experiments under discussion, the straight-line relationship holding for plant populations between 400 and 1000 are (approx. 16,000 and 40,500 acre). E.M.A.

Distribution of tillers of plant species in old permanent grassland with different types of use. D. M. de Vries and B. J. Hoogers, *Netherlands J. agric. Sci.*, 1959, **7**, 232–6.

A method is described by which swards were analysed and distribution of the plant species over the field recorded. Dominance frequency (DF) is defined as the number of sampling units in which a species takes the first place and presence frequency (PF) as the number of sampling units in which that same species is found. The value $(DF/PF) \times 100$ is called the dominance tendency (Dt). In this survey covering 1647 old permanent grasslands 29 common grassland species are tabulated in alphabetical order and their Dt values shown for pure hayfields, a hay pasture (one cut of hay with grazing afterwards), alternate pasture (cutting for hay with grazing before and afterwards in some years with grazing only in others) and pure pasture (grazing only). Tuft-forming species are characterized by high Dt values with PF considerably below 100%; species spread by stolons or rhizomes or spread by seed (unless they are tall) have high PF but low DF values, hence low Dt ratings. Tiller distribution depends not only on mode of propagation but also on grassland usage. In hayfields, tall quickly growing species dominate in a struggle for light. Species propagated by seed have a good chance of germinating in a hayfield but are often eliminated at a young growth stage by grazing. In grazed fields, species propagated by vegetative growth dominate. Among the species most affected by the use to which the pasture is put are *Agrostis stolonifera*, *Dactylis glomerata*, *Festuca pratensis*, *Festuca rubra*, *Holcus lanatus*, *Juncus effusus*, *Lolium perenne*, *Poa pratensis*, *Trifolium repens* and *Trisetum flavescens*.

E.M.A.

The influence of time of tiller origin and nitrogen level on the floral initiation and ear emergence of four pasture grasses. J. R. Wilson. *N.Z.J. agric. Res.*, 1959, **2**, 915–32.

This study was undertaken at Palmerston North on perennial ryegrass, Italian ryegrass, cocksfoot and timothy to obtain information on the development of individual tillers formed throughout the year under both high (6N) and low (1N) levels of ammonium nitrate, equivalent to at least 600 lb. and 100 lb. respectively of the fertilizer per acre. At four-weekly intervals from May 1958 to February 1959 100 tillers per species per N level were tagged at the two-leaf stage; dates of ear emergence and leaf number at ear emergence were recorded, and the date of floral initiation was determined per tagged tiller. In all species (but more pronouncedly with the ryegrasses and timothy) the number of days to floral initiation and ear emergence decreased as the date for tiller origin grew later, so that the periods of floral primordia initiation and ear emergence were relatively short. High levels of nitrogen accentuated this fact, especially in cocksfoot, where floral initiation and ear emergence were three weeks earlier. The minimum number of days between floral initiation and ear emergence was 30 days for perennial ryegrass, 21 for Italian ryegrass, 32 for timothy and 24 for cocksfoot. There was almost complete absence of floral initiation after December. Mean leaf number at ear emergence decreased with the tillers of later origin with a minimum of 6 for perennial ryegrass, 7 for Italian ryegrass, 14 for timothy and 9 for cocksfoot. With the two ryegrass species the number of fertile tillers formed was high throughout the trial period, whereas for cocksfoot and timothy the percentage of fertile tillers was only high for those formed before mid-winter. Nitrogen increased the percentage of fertile tillers in all species. The heading of perennial ryegrass was inhibited by controlling the day/night temperature at 90°/70° F. over a seven-week period. E.M.A.

CROP PROTECTION

Effects of certain climatic factors on the toxicities of several organic phosphorus insecticides. B. G. Hightower and D. F. Martin, *J. econ. Ent.*, 1958, **51**, 669–71.

In laboratory trials carried out in Texas in 1956 to assess the effects of wind, rain and high temperature on the effectiveness of deposits of organophosphorus insecticides as sprays and dusts against *Anthonomus grandis* on cotton and against *Tetranychus tumidus* in comparison with chlorinated hydrocarbon compounds, wind and rain both reduced the toxicity of parathion and methyl-parathion, rain reduced that of malathion, and a temperature range of 78–102° F reduced that of Phosdrin, all as sprays. Of dust applications, wind reduced the toxicity of Gusathion but not of toxaphene or dieldrin, although the latter lost its toxicity from other causes. High temperatures reduced the toxicity of spray deposits of endrin, dieldrin and Gusathion, but not of toxaphene. In the trials against *T. tumidus*, the toxicity of Gusathion was reduced by rain 1 hour after application but not by rain after 24 hours, and at low application rates wind and rain had little effect on parathion or methyl-parathion, although rain rendered Gusathion less effective. D.L.

Secondary physiological effects of DDT in *Galleria* larvae. R. L. Beard, *Ent. exp. appl.*, 1958, **1**, 260–7.

Although DDT is relatively harmless to larvae of *Galleria mellonella* by external application, it induces convulsive movements, weakness and death when injected. Larvae already parasitised by a Braconid do not respond to injection with DDT in the same way, and although the body may contain a lethal quantity death is not hastened. Comparisons of larvae treated with DDT or with an extract of the venom from the parasite indicated that adenosine triphosphate became depleted after death, and was not an effect of treatment with DDT. Regurgitation, which sometimes occurs before death from DDT poisoning, is a direct effect of DDT, and prostration as a secondary effect is accompanied by a loss of adenosine triphosphate. Larvae injected with adenosine triphosphate after having been injected with DDT sometimes recovered. D.L.

The effects of storage of vegetable seeds treated with fungicides and insecticides on germination and field stand. D. J. de Zeeuw, G. E. Guyer, A. L. Wells and R. A. Davis, *Plant Dis. Reptr*, 1959, **43**, 213–20.

Pea, bean and cucumber seeds were treated at recommended rates in 1956 with 10 insecticides, 31 fungicides and 9 proprietary insecticide-fungicide mixtures. Field plantings and laboratory germination tests of each batch were carried out in 1956, 1957 and 1958. Results of the field trials with the three crops in all years indicated that organic fungicides alone and in combination with certain insecticides were superior to mercurials and to insecticides alone. The use of insecticides as a group led to poor stands of beans, but the emergence of peas and cucumbers was not seriously impaired. There was no apparent increase in damage with prolonged storage, except with volatile mercurials on peas and beans. Germination tests gave higher figures, based on observations of root and shoot emergence, than did the field trials. D.L.

Vancomycin, a potential agent for plant disease prevention. P. P. Mehta, D. Gottlieb and D. Powell, *Phytopathology*, 1959, **49**, 177–83.

Vancomycin, an antibiotic produced by *Streptomyces orientalis*, inhibits the development of a wide range of Gram-positive and Gram-negative plant pathogens. *Corynebacterium tritici* was the most sensitive organism tested *in vitro*, being inhibited by vancomyicin at less than 0·1 μg./ml. in 48 hours; *Xanthomonas campestris*, *Pseudomonas phaseolicola* and *P. syringae* were inhibited by less than 1 μg./ml., but other Pseudomonads required a rate of more than 500 μg./ml., as also did *Agrobacterium tumefaciens*. *Erwinia amylovora* was controlled at 2·5 μg./ml. Vancomycin is relatively stable, and withstood an hour's exposure to a temperature of 100° C at a *p*H level near neutrality without detectable loss of activity. It is very readily absorbed by the leaves and roots of a variety of plants; concentrations of up to 36 μg./ml. were found in the primary leaves and roots after seeds of tomato, cucumber and pepper had been soaked for 12 hours in a concentration of 100 μg./ml. There tends to be a linear relationship between the concentration of vancomycin supplied to the plant and the amount absorbed. Translocation occurs in both upward and downward directions, and the spraying of a single leaf often resulted in root concentrations in excess of those required to inhibit many bacteria *in vitro*. Absorption from the soil is rapid, but so is inactivation in non-sterile soils; the concentration recovered from such soil was halved in less than 3 days, whereas it remained constantly high for at least 2 weeks in sterile soil. No phytotoxicity was recorded, even at rates of 1000 μg./ml. D.L.

Chemical control of cereal rusts. IV. The influence of nickel compounds on wheat, oat, and sunflower rusts in the greenhouse. F. R. Forsyth and B. Perutson, *Phytopathology*, 1959, **49**, 1–3.

The nitrate and chloride salts of nickel were shown to be as effective at 70 p.p.m. as a nickel-salt amine compound at 280 p.p.m. as eradicant sprays when they were used on seedlings of wheat infected with leaf rust (*Puccinia rubigo-vera*) and stem rust (*P. graminis*), of oats infected with crown rust (*P. coronata*), and of sunflower infected with *P. helianthi* in greenhouse tests. They acted most efficiently when the uredia had ruptured the epidermis of the plant, but were of no value when sporulation had proceeded for two days. The trials, conducted at Winnipeg, also established the value of these materials as protectant sprays when used before inoculation, but the sulphate, fluoride and acetate salts were less effective. The amine compound was more resistant than the salts to removal by simulated rainfall. Symptoms of phytotoxicity developed in oats and sunflower seedlings when the salts were applied at higher concentrations. D.L.

Effect of benzimidazole, dimethylbenzimidazole, glucose, and metal ions on the development of *Puccinia graminis tritici* on detached leaves of Khapli wheat. D. Wang, *Canad. J. Bot.*, 1959, **37**, 239–44.

Investigations at the University of Manitoba have shown that the inhibitive effect of benzimidazole on the infection of Khapli wheat by *Puccinia graminis* f. *tritici* may be reversed by 5,6-dimethylbenzimidazole, which acts as an antagonist, or by glucose applied from outside sources. In the latter case, it is thought that the glucose probably forms a glucoside with benzimidazole, but as there was no close relationship between the concentration of benzimidazole and its inhibition by glucose the existence of other factors is suspected. The resistance imparted by benzimidazole was restored when cobalt in solution with glucose and benzimidazole or 5,6-dimethylbenzimidazole was used, but not by cobalt alone or combined separately with the other compounds. It is concluded that benzimidazole or its derivative in the plant with cobalt may produce a factor similar to vitamin B_{12}, and thus be required for normal metabolism by the plant. D.L.

Effect of potash on powdery mildew in wheat. M. D. Glynne. *Plant Path.*, 1959, **8**, 15–16.

The incidence of powdery mildew, *Erysiphe graminis*, on wheat was determined on seven of the permanent wheat plots of Broadbalk field, Rothamsted, to obtain evidence in support of the common idea that potash deficiency increases the severity of the disease. Fifty top and fifty second leaves from each of seven plots were selected at random and classified according to the proportion of their areas covered with mildew pustules. Details are given of the differential manurial treatment for the seven plots selected and results indicate that powdery mildew was severest on plots with unbalanced manurial treatments, being most severe on plots receiving N and P but less on plots receiving N alone. The addition of potash reduced the incidence of powdery mildew on all plots significantly. The addition of sodium or magnesium was without effect. On all plots a preceding year of fallow increased the disease incidence, probably by increasing available nitrogen supply without affecting that of potash. The low incidence on the plot receiving 14 tons of farmyard manure is attributed to the high rate of potash added to this soil compared with those receiving mineral fertilizers. E.M.A.

"Brusone" disease of rice in Hungary. R. Vámos, *Plant and Soil*, 1959, **11**, 65–77.

"Brusone" causes considerable damage on acidic soils, especially in cool summers. The primary cause of the disease is H_2S formed under the anaerobic conditions of the flooded paddy soil. In sunny weather the plant produces enough oxygen to oxidize the H_2S but in cool dull weather insufficient oxygen is formed and the H_2S kills the roots. Adventitious roots develop on the stem but they are unable to take up sufficient nutrients and metabolic disturbances ensue. It is only after this stage that fungi appear. S.F.A.

Fungicidal control of club root. W. R. Rosser, *Plant Path.*, 1959, **8**, 13–15.

In a trial carried out in 1956, pentachloronitrobenzene (PCNB) gave good control of club root of brassicas (caused by *Plasmodiophora brassicae*) when it was used as a root dip at transplanting, but there was no correlation with increased yield because of probable phytotoxicity in the rhizosphere. The question was therefore further investigated in 1957. PCNB dust was applied to the soil at rates equivalent to 30 and 60 lb./acre, and tetrachloronitrobenzene (TCNB) dust at 8 lb./acre, both 13 days before planting out in June, and liquid treatments with 1 : 2000 mercuric chloride or 1 : 320 PCNB made immediately before planting out at a rate of ½ pt./plant. The liquid PCNB treatment was the only one to check plant growth, and nearly all the plants in that test died by the end of July; the plot was replanted, each plant being placed in the original dibble holes as nearly as possible. All plants in the trials were harvested in early October. Most healthy plants were from plots treated with mercuric chloride, but the greatest reduction in symptoms of club root was in the replants of the liquid PCNB-treated plots, where 118 plants out of 136 were free of disease, as compared with 25, 21, 19 and 53 from those treated with PCNB at 30 and 60 lb./acre, TCNB, and mercuric chloride respectively. D.L.

Treatment of field boxes for the control of post-harvest rots of peaches and storage rots of apples. R. E. Adams and S. E. Tamburo, *Plant Dis. Reptr*, 1959, **43**, 396–400.

Boxes used for the harvesting and storage of apples at the West Virginia Agricultural Experiment Station were artificially contaminated in 1957 with a suspension of spores of 12 species of fungi implicated in storage rots. After drying, they were sprayed with fungicides to the point of run-off. After 10 weeks in refrigerated storage, 14·5% of Red Delicious apples had rotted in untreated boxes, whereas percentages of 7·4, 4·9, 4·3, 5·1, 3·0, 7·5 and 3·2 were recorded from boxes that had been treated with mercuric chloride at 1 : 1000, cycloheximide at 5 p.p.m., copper sulphate at 4 lb./100 gal., captan at 2 lb./100 gal., glyodin at 1 qt/100 gal., and maneb and zineb at 2 lb./100 gal., respectively. Similar results were obtained in 1958 with other varieties of apple, using captan, zineb, and glyodin, and also amobam at 1 qt/100 gal. With peaches, the percentage of rotting in one trial was reduced from 44·9, 12 days after harvest, to 12·1, 3·6, 7·8 and 6·9 with captan, zineb, amobam and sulphur (at 5 lb./100 gal.), respectively, and to 1·0 by the use of a cardboard box-liner. In another trial, in which the boxes were more heavily contaminated, the corresponding figures were 44·9, 46·6, 50·9 and 46·6, with 14·8 using liners, as compared with 74·8 in the control. D.L

The infection of pruning wounds by *Gloeosporium perennans*. A. T. K. Corke, *J. hort. Sci.*, 1959, **34**, 85–95.

In the study of the effects of pruning young wood of the apple variety Cox's Orange Pippin on infection by *Gloeosporium perennans*, carried out at Long Ashton Research Station, inoculations were made every four months from November 1955 to March 1957, and then every two months until September of that year. It was found that the tips of annual shoots, when pruned, were susceptible to spore infection all through the year, and that cankers induced in November were much more injurious than those induced in July. Similarly, the production of spores from November-pruned shoots was greater than those pruned in March, although both types of shoot began to produce spores one month after pruning. Shoots infected in July, however, did not begin to sporulate until December, and then only sparsely. Spore production reached a peak in June and July of the year following pruning. D.L.

The nature of soil transmission in soil-borne plant viruses. Y. Miyamoto, *Virology*, 1959, **7**, 250–1.

Soil in which had been buried the macerated tissues of wheat and barley plants, infected with their respective yellow mosaic viruses, proved infective when plants were grown in it two years later at Hyogo University, Japan. Seeds sown in pellets made from fractions of the soil were also infected, and so were plants rubbed with the soil. The clay fraction, in which the particle size was less than 2μ in diameter, was more infectious than fractions containing larger particles, and even a mud made from the clay fraction carried infection. These findings accord with the hypothesis that soil-borne viruses are adsorbed by clay particles, although it was found that clay fractions composed of larger particles were not so effective. D.L.

Some properties of an inhibitor of virus infection from leaves of raspberry. C. H. Cadman, *J. gen. Microbiol.*, 1959, **20**, 113–28.

Further studies on a substance in raspberry leaves that prevents infection by plant viruses have shown that it is precipitated by nicotine or protein, passes through a dialysing membrane, and is unaffected in its action by extremes of temperature; it will withstand boiling. The compound is believed to be a phenolic tanning agent, and its presence has also been demonstrated in the leaves of plum, cherry and strawberry, and to a lesser extent in peach and apple. The extent of its inhibition varied with the virus tested, and its inhibition of the viruses of potato ring necrosis, tobacco mosaic and tobacco necrosis was found to be directly related to the quantity of virus present, and in turn with the amount of tannin in the compound. The infectivity of raspberry leaf extracts containing ringspot virus or the beet ring spot strain of tomato black ring virus was found to vary inversely with the tannin concentration and with *p*H. Increased *p*H values led to a decrease in the concentration of virus present. D.L.

Die sterile Verzwergung des Hafers in der Tschechoslowakischen Republik. (Sterile dwarfing of oats in the Czechoslovakian Republic.) V. Průša, *Phytopath. Z.*, 1958, **33**, 99–107.

Heavy losses of cereals, especially oats, were suffered in Czechoslovakia in 1956 from a previously undescribed virus disease. Infected oat plants were less than a third of their normal height, the number of tillers was increased, and panicles failed to develop. Apart from dwarfing, the most obvious symptom of the disease in the field was a yellowing of the bases of the youngest leaves, followed by a striking anthocyanin staining that proceeded downwards from the leaf tips. It is suggested that the condition be named "sterile dwarf virus disease of oats"; symptoms on barley and wheat were similar, but although rye was also attacked it suffered less injury. In 1957 the spread of the disease was found to be associated with the bug *Calligypona pellucida*, in which it proved to be persistent. Infection of oats was reduced by 28% in a field trial with Sytam (45% schradan). D.L.

The effect of nitrogen, phosphorus and potassium levels on growth and virus content of excised tobacco-mosaic-infected tomato roots. (Abstract.) A. Papasolomoutos and R. E. Wilkinson, *Phytopathology*, 1959. **49**, 229,

The nutritional requirements of healthy and TMV-infected excised tomato roots were investigated by measuring their comparative growth in modified culture solutions. In a normal solution the diseased roots were shorter and produced fewer laterals, but, when the levels of nitrogen or phosphorus were increased to a point that caused stunting of healthy roots, the diseased roots were as long as, or even longer than, the healthy ones. Differences in potassium requirements were not apparent. The virus concentration in the infected roots, as assayed *in vivo* on *Nicotiana glutinosa*, increased as the level of nitrogen or phosphorus in the culture solution was increased from sub-normal to above-normal amounts. The results support the theory that the systems responsible for producing normal plant proteins and virus proteins compete for available nitrogen and phosphorus. D.L.

Control of Pythium root rot by the nematode ***Aphelenchus avenae*****.** H. L. Rhoades and M. B. Linford, *Plant Dis. Reptr*, 1959, **43**, 323–28.

In greenhouse pot tests carried out at Urbana, Illinois, maize sown in autoclaved soil developed severe root rot when the soil was inoculated with mycelium of *Pythium arrhenomanes*, yet the disease occurred only mildly when the soil was also inoculated with 125,000 nematodes (*Aphelenchus avenae*) per pot. The mean dry weight of plants four weeks after sowing was 4·5 g. with the nematodes alone, 4·49 g. in uninoculated controls, 4·42 g. with the nematodes and *Pythium*, and 1·1 g. with *Pythium* alone. The nematode fed destructively on *Pythium* in the laboratory; in the greenhouse it invaded *Pythium* lesions on maize roots, but it did not attempt to feed on healthy roots. D.L.

Les nématodes et le flétrissement des cotonniers dans le sud-ouest de Madagascar. (Nematodes and cotton wilt in South-West Madagascar.) M. Luc, *Cot. Fibres trop.*, 1958, **13**, 239–56.

In Madagascar, two types of wilt in cotton plantings are encountered. One, associated with grey alluvial soils, is not parasitic and is believed to be caused by high concentrations of chlorine in the soil or by unsuitable soil structure; the other, which is parasitic, is caused by a fungal complex including several species of *Fusarium* but not *F. vasinfectum*. Nematodes of five species, two of which are described as new, were found on the roots of both sound and diseased plants, and their presence is presumed to allow the fungi to penetrate the roots more readily. D.L.

ANIMAL HUSBANDRY

A comparison of the relative efficiency of three pasture utilization systems. C. H. Gordon, O. J. Hunt, G. R. Mowry and W. R. Harvey, *J. Dairy Sci.*, 1959, **42**, 1686–97.

This experiment compares rotational, strip and zero grazing or soilage by milking herds on improved pastures typical of the Beltsville area. The trial continued over three grazing seasons from 1954 to 1956, four one-acre plots of an orchard grass/ladino clover sward established in 1953 being used for each treatment. The effects of treatments were studied on (*a*) total nutrients utilized per acre, (*b*) production of milking cows, (*c*) relative needs of cows for grain supplements and (*d*) grass/legume ratio in the sward. Details are given for the initial and final grazings or cuttings of each plot; forage in excess of the needs of the experimental animals was removed for hay or silage and the TDN credited to the appropriate system. Additions of commercial fertilizers were the same for each plot, but manure was added to the soilage areas to compensate for the lack of droppings from grazing animals. Dates and rates of fertilizer application are shown. The three-year average for total forage utilized by the grazing dairy cows was: rotationally grazed plots 2875, strip-grazed plots 2947, soilage plots 2431 lb. TDN/acre. Neither the milk production nor the live weight changes were significantly affected by the method of providing forage. Production per cow was increased by grain supplements, but no significant interaction existed between utilization system and supplementation. The legume content of the sward on all areas fell rapidly during the experimental period. E.M.A.

Factors influencing the composition and nutritive value of herbage from fescue and *Molinia* areas. R. O. Davies, D. I. H. Jones and W. E. J. Milton, *J. agric. Sci.*, 1959, **53**, 268–85.

Plots at three sites near Aberystwyth had been treated as follows since 1930: no fertilizer or lime; 4 cwt/acre superphosphate each year; 2 ton/acre limestone every 5th year; NPK (1 cwt/acre ammonium sulphate, 4 cwt/acre superphosphate, 4 cwt/acre kainit) every year; NPK every year and lime every 5th year. At each site five fenced plots were grazed by sheep six times a year; at two sites there were also five unfenced plots, a hay plot receiving no fertilizer or lime, and a hay plot receiving NPK+lime. In 1954 the unenclosed plots were also fenced and all plots were cut three times. The vegetation of all the untreated plots and all the free-grazed plots was dominated by fescue, bent and *Molinia*; on the enclosed plots the P and NPK treatments gave swards in which meadow grasses and Yorkshire Fog predominated, whereas the lime and NPK+lime plots were comparable to good lowland permanent pasture. Dry matter and protein yields were higher after controlled grazing than after free grazing; NPK+lime outyielded P, lime, and NPK, which outyielded the control; grazed plots receiving no fertilizer or lime outyielded plots receiving NPK+lime from which hay and aftermath had been removed. When fed to sheep the produce from the limed areas gave higher live-weight gains, higher digestibility and higher mineral retention than the same weight of produce from unlimed areas. In a later trial with sheep fed a fescue hay of low calcium content, live-weight gains, digestibility and mineral retention were improved by feeding a calcium carbonate supplement. S.F.A.

The metabolic changes which occur in sheep transferred to lush spring grass. I. Changes in blood and rumen constituents. II. Changes in the acid-base balance of the whole animal. E. F. Annison, D. Lewis and D. B. Lindsay, *J. agric. Sci.*, 1959, **53**, 34–41, 42-5.

Blood and rumen samples were taken at 2-hour intervals on 28th March and 3rd, 5th, 8th and 24th April from three wethers fed on hay alone, hay+casein, and hay+flaked maize. After turning out on 3rd April, rumen volatile fatty acids, rumen and blood ammonia, and blood urea of all sheep rose and remained high. Total blood volatile fatty acids and rumen α-amino N rose markedly but returned to normal within 3 days. Rumen and blood lactic acid, blood glucose, blood chloride and serum sodium also rose temporarily but took 3 weeks or more to return to the original values. Serum magnesium fell to a minimum on the 13th day and returned to the original value after 3 weeks. Blood ketone bodies, blood α-amino N, serum potassium and serum calcium remained unchanged. Blood pH and plasma total CO_2 were unchanged in the sheep that had had hay alone, but the others showed appreciable acidosis by the 3rd day after turning out, after which the figures gradually returned to normal; a subsidiary experiment suggested that exercise and excitement had little effect on the changes in acid-base balance. No symptoms of clinical disorder were observed in any of the sheep. S.F.A.

Studies on the magnesium status of grassland herbage and its possible significance in animal health. A comparison of various forms of magnesium applied as a fertilizer dressing. T. W. Griffiths, *J. Brit. Grassl. Soc.*, 1959, **14**, 199–205.

Treatments applied to a Cockle Park type ley sown in 1954 were: (1) no magnesium, (2) magnesium limestone (30% $MgCO_3$) 2 ton/acre in spring 1955, (3) commercial magnesite (88% MgO) 25 cwt/acre in spring 1955, (4) magnesium sulphate ($MgSO_4.7H_2O$) 3 cwt/acre/year in spring each year (1955–7), (5) commercial magnesite (88% MgO) 5 cwt/acre in spring 1956. Yields were significantly increased by (2) each year and by (3) and (5) in 1957, but (4) was ineffective. Magnesium content of the herbage was increased by all treatments; each year (3) had most effect, then (2) and (5), while (4) was little better than the control. Irrespective of the magnesium level in the plant, its concentration tended to increase to a maximum in July or August and then remain fairly constant for the rest of the growing season, but weather which stimulated growth tended to depress magnesium content. Increasing the magnesium content had little effect on its distribution within the plant. As expected, (2) increased the Ca content of herbage but decreased K, whereas (3) and (5) tended to depress both Ca and K. S.F.A.

Some factors affecting silage fermentation. 1. Influence of laceration and storage temperature. G. W. Wieringa, *Netherlands J. agric. Sci.*, 1959, **7**, 134–7.

Experimental silages were made in one-litre or two-litre jars with grass cut from permanent pastures in August or September and either chopped with a hay chopper into 5 cm. pieces or minced in a meat mincer, and incubated at 20° and 35° C. Results of determinations of lactic acid bacteria, pH development, butyric acid production and protein breakdown are presented graphically. Mincing caused an increase in lactic acid bacteria and decreases in butyric acid production, pH and protein breakdown, indicating a liberation of sugars to provide a valuable substrate for lactic acid bacteria growth. The effect of storage temperature was not constant and a second experiment was therefore conducted to compare the effect of lacerating and storage at either 20° or 30° C with the addition of molasses (1, 2, 3, or 4%) and storage at 30° C. From the table giving the chemical composition it is clear that laceration has the same effect as sugar additives, but 4% molasses addition appears necessary for good preservation. It is emphasized that when ensiling lacerated grass it is just as important to maintain a low temperature as when ensiling an untreated crop and that laceration cannot improve silage quality when the sugar content of the grass is low or when the temperature in the silage approximates to the optimum for butyric acid bacteria growth. E.M.A.

Pelleted rations compared to similar rations fed chopped or ground for steers and lambs. W. C. Weir and others, *J. Anim. Sci.*, 1959, **18**, 805–14.

Three trials are reported in this paper. In the first lambs were hand-fed rations in which chopped or pelleted dehydrated lucerne supplied 100% or 70% of the feed, ground barley providing the remainder. Tables show the composition of the rations and also the weight gains, feed consumption and carcass quality. Pelleting increased the daily feed intake, daily liveweight gain, efficiency of feed utilization and carcass quality. In a digestion trial pelleting lowered the digestion coefficient of crude fibre without influencing the TDN content. Addition of barley decreased feed intake, but increased efficiency of feed utilization. It decreased the crude fibre digestibility in the pelleted rations only. In the second trial steers were fed 2 lb. barley and 2 lb. long oat hay daily for 167 days together with either lucerne as pellets or hay to appetite. Feed intake, average daily gain and feed efficiency were all higher in the case of pellet-fed animals. In the third trial lucerne as pellets or meal supplied 100%, 70% or 40% of the ration, the remainder being concentrates in the form of barley and molasses dried beet pulp. Significant interactions were shown between ration preparation and concentrate level. Feed intake was significantly lower on the meal ration than on the pellet ration when no concentrates were fed, no significant difference was shown at the 30% concentrate level and a lower intake at the 60% concentrate level. Carcass data favour rations of pellets and concentrates. E.M.A.

The value of supplemental trace minerals in cattle fattening rations. R. R. Oltjen, E. F. Smith, B. A. Koch and F. H. Baker, *J. Anim. Sci.*, 1959, **18**, 1196–200.

Four experiments were conducted involving 80 animals, either steers or heifer yearlings. Where a mineralized salt containing 0·170% Mn, 0·175% Fe, 0·033% Cu, 0·010% Co, 0·007% I and 99·058% NaCl was offered free choice with a ration of coarse ground sorghum grain, cottonseed oil meal pellets, hay and ground limestone no significant differences were shown in the daily live-weight gains of the steers (2·65 lb. for the controls, 2·60 lb. for the mineral-fed animals). Similarly when the minerals were added as a pre-mix to the protein concentrate to supply in mg./head daily 56·3 Mn, 1·97 I, 1·25 Co, 46·13 Fe, 3·65 Cu and 3·42 Zn, together with a ration of ground sorghum grain, hay, soyabean meal, salt and ground limestone, no significant differences were seen in the daily live-weight gains or feed utilization in steers (2·48 lb. for control group, 2·55 lb. for mineral-fed group in daily live-weight gain). In two experiments, one with steers and the other with heifers, where the pre-mix minerals were added to a ration consisting of ground maize, soyabean pellets, hay and ground limestone and salt, the steers fed trace minerals gained 0·58 lb. and the heifers 0·37 lb. more than their respective control groups daily. In these two cases the mineral feed also led to greater grain consumption and improved feed utilization. The findings are in accordance with previous experimental evidence, but it is stated that, although sorghum grain has a somewhat higher mineral status than maize, the differences in response to minerals with the various rations cannot be wholly attributed to this. E.M.A.

Effect on reproduction of feeding diethylstilbestrol to dairy cattle. C. B. Browing, G. B. Marion, F. C. Fountaine and H. T. Gier, *J. Dairy Sci.*, 1959, **42**, 1351–8.

Thirty-one cows, including five pairs of identical twins, at various stages of gestation and lactation were fed 0, 5, 10, 15 or 20 mg. diethylstilboestrol (DES) per 1000 lb. body weight during 1–4 successive lactations. Details are given of the number of days on which DES was fed both prior to and after conception and of the number of services per conception during the pre-treatment and trial periods. There was no effect whatsoever on the ovaries of any DES-fed cow, suggesting that only a small amount of the hormone injected was actually absorbed—a theory also supported by the lack of treatment effect on physical appearance or on pituitary and adrenal glands. Results indicate that oral administration of 5–15 mg DES has no harmful effect on pregnancy but since three of the animals fed the 20 mg level aborted it is suggested that it is possibly unsafe to feed DES to dairy cows at levels higher than 15 mg per 1000 lb. body weight. Hyperemia of the volva, simulating oestrus, was encountered in most of the treated animals but this condition was neither persistent nor proportional to the level of DES fed and varied with the individual animal. E.M.A.

Trials with hexoestrol for beef production. G. C. Everitt, *N.Z.J. Agric.*, 1959, **99**, 360.

The influence of the sex hormone hexoestrol upon the fattening performance of beef steers was investigated in several trials in New Zealand. In controlled experiments in which hexoestrol in pellet form was implanted under the skin on the outside of an ear, a dose of 60 mg. to 2-year-old beasts increased the live-weight gain by 70 lb. during 107 days; and a dose of 90 mg. to 5-year-old steers increased this by 54 lb. over 90 days. In terms of carcass weight the gains were only 28 lb. and 22 lb. in the two groups respectively. Carcass quality as judged by standard butchers' criteria was virtually the same in treated and untreated animals. In field trials on several farms a dose of 30 mg. or 45 mg. produced a live-weight gain 10–30% greater than that of untreated beasts. The smaller dose seemed quite sufficient for Angus steers 2–3 years old. Here again carcass weight and quality were less well improved. In general a reasonable case seems to have been demonstrated for the use of hexoestrol for fattening steers under veterinary supervision. J.T.E.

Biuret—a source of NPN [non-protein nitrogen] **for ruminants.** E. E. Hatfield and others, *J. Anim. Sci.*, 1959, **18**, 1208–19.

In toxicity tests a penned ewe that had been kept without food for 10 hours was fed three equal portions of a ration of 375 g. biuret mixed with a 10 lb. fattening ration at 12-hour intervals. There were no visible symptoms of toxicity or indications of unusual after-effects. There were no abnormal reactions or toxicity symptoms when three ewes weighing 133–155 lb. were administered drenches of 30 g., 60 g. and 90 g respectively. Drenches of 175 g. and 275 g. biuret to two wether lambs of weight 85 lb. each caused symptoms of distress during the first 36 hours after treatment, but after 5 days the lambs were eating well and acting normally. In metabolism tests wether lambs of weight 64–72 lb. were fed at levels of 300 or 450 g. twice daily on a basal ration containing 0·332% nitrogen supplemented with urea, urea plus biuret, or biuret alone to provide equal additional nitrogen. Nitrogen intake and apparent digestibility of the nitrogen were determined. At the lower level of feed intake lambs retained significantly more nitrogen from the "biuret" ration than from the "urea" ration, and at the higher level of feeding "urea-biuret" ration gave the highest nitrogen balance. In trials with steer calves, average weight 425 lb., chopped hay was supplemented with either urea, biuret or soyabean meal to act as the main source of N. The digestion coefficient for nitrogen and also the nitrogen balance was lower for the "biuret" than for the other two rations. In growth and reproduction studies with wether and ewe lambs of average weight 70 lb. either urea or biuret was used to supply two-thirds of the 2% nitrogen in the rations, which were self-fed. Satisfactory growth and reproduction were obtained. Utilization of biuret nitrogen in comparison with urea nitrogen appeared to be influenced by the level of feed intake. E.M.A.

Grazing management of native pastures in the New England region of New South Wales. 1. Pasture and sheep production with special reference to systems of grazing and internal parasites. R. Roe, W. H. Southcott and H. N. Turner, *Aust. J. agric. Res.*, 1959, **10**, 530–54.

A four-year-grazing experiment with Merino sheep on a native pasture dominated by *Bothrichloa ambigua* compared continuous grazing at 1 sheep per 1·25, 1·0 or 0·75 acres with 1 sheep per acre rotational grazing through 4 sub-plots.

Sub-treatments of drenching or non-drenching with phenothiazine were also included. No consistently significant differences between grazing treatments in their effects on the pasture or on sheep live-weights were recorded. During the last three years, however, total forage available was less under the heavier stocking, and on all plots production increased in spring and declined to a low level in winter. Crude protein and P content of the herbage was also highest in spring. Sheep liveweight increases followed the pattern of herbage production. More wool per acre was produced from the heavier stocking rates. Drenching gave increased live-weight gain in sheep and improved wool production and reduced the egg counts of the parasites *Oesophagostomum* spp. and *Haemonchus contortus* but was less effective against *Trichostrongylus-Ostertagia.* E.M.A.

Prevention of swayback in lambs. R. Allcroft, F. G. Clegg and I. Uvarov, *Vet. Rec.*, 1959, **71**, 884.

Although swayback can sometimes be prevented by applying copper sulphate to pasture land on which ewes are held, the method is not always successful and the need arises for individual administration of copper to ewes during gestation. The intravenous injection of copper sulphate has been found to be effective, but this method is only applicable by veterinary surgeons. Copper sulphate solution is much too irritant to inject under the skin or into muscle, and a less irritant salt of copper is called for. Such a salt is copper glycine (Copper "45" Injection, Glaxo). On a sheep farm in Derbyshire having a history of swayback, copper glycine was administered to 64 breeding ewes either by subcutaneous or intramuscular injection at a time when the ewes could be presumed to be in mid-gestation (January). The effect was judged by the incidence of swayback in the lambs of the treated ewes in comparison with the lambs of 64 untreated ewes on the same farm. Eventually swayback was diagnosed in one lamb from a treated ewe and in 10 lambs from untreated ewes. The value of copper glycine thus appeared to be positive and highly significant. Treatment raised the blood copper content of the ewes from about 0·01 to 0·07 mg./100 ml., i.e. a severe copper deficiency was restored to normal by the single treatment. The copper glycine, as formulated, was not seriously irritant to muscle or subcutaneous tissue, and subcutaneous injection is regarded by the authors as the most suitable method of administering the chemical. J.T.E.

Low-level feeding of Hygromycin B and phenothiazine NF for the control of *Ascaridia galli* and *Heterakis gallinae* in broilers. J. M. Dixon *et al.*, *Poult. Sci.*, 1959, **38**, 1199.

In experiments carried out in the U.S.A. chicks were reared in houses having an earth floor, which was heavily infected with eggs of the roundworms *Ascaridia galli* and *Heterakis gallinae*, and they were fed on a soybean oil meal ration to which was added by thorough mixing Hygromycin B at 7·2 mg./ton or phenothiazine at 0·5 kg./ton or both these substances. (Hygromycin B is an antibiotic produced from cultures of *Streptomyces hygroscopicus*). Fowls receiving both anthelmintics in the feed harboured hardly any worms; Hygromycin B was nearly as effective; phenothiazine came third, being of definite value. J.T.E.

Mixed grazing and Nematodirus disease of lambs. J. T. Baxter, *Vet. Rec.*, 1959, **71**, 820.

Experiments carried out in Northern Ireland in 1957 and 1958 confirmed that *Nematodirus* larvae can survive throughout the winter in grass herbage and that they become maximally infective for lambs during the last two weeks of March and early in April. In 1957 two ewes with 4 lambs were put in each of 4 one-third acre plots known to have been infected with *N. battus* and *N. filicollis* during 1956. Eleven of the lambs became clinically infested. In 1958 the plots were similarly stocked, and in addition two calves spent several periods of a few days in two of the plots. The calves became infested and probably increased the infestation risk to the lambs. Two lambs died from nematodiriasis, three became severely affected and five mildly affected. The results from these small experiments did not permit further precise conclusions to be made, but it did appear that overstocking increases susceptibility to nematodiriasis, for the larvae were found to be more numerous on the lowest inch or two of grass than on the higher parts of the herbage. J.T.E.

Selenium and animal health. W. J. Hartley *et al.*, *N.Z.J. Agric.*, 1959, **99**, 259.

Selenium was known simply as a poisonous element which can harm livestock grazing on seleniferous soils, until research upon vitamin E deficiency showed that selenium can replace this vitamin in certain diets. Vitamin E as α-tocopherol acetate has been known for some years to be valuable in the treatment of "white muscle disease" in lambs in New Zealand. Lambs may be congenitally affected and survive only a few days; but they can also acquire the disease, and then they show the typical stiff gait and muscular weakness. The lesion is a degenerative condition of the skeletal and heart muscles, which show white patches. The value of selenium in "white muscle disease" was studied at Wallaceville, New Zealand, and it was found that a lamb dose of 1 mg. of selenium was more effective than 300 mg. of tocopherol in preventing the disease, death losses being almost stopped by the former, and halved by the latter, in trials on 16 properties. Ways of exploiting this discovery are currently under study. J.T.E.

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